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RPP-RPT-27406, Rev. 1

Demonstration Retrieval Data Report for Single-Shell Tank 241-S-112

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Abstract: Single-shell tank S-112 waste was retrieved to the limit of salt dissolution technology. Data are presented from the retrieval campaign including retrieval system performance, leak detection monitoring and mitigation results, residual waste heel estimates, and the potential long-term risk. This retrieval data report addresses format and data requirements of the Hanford Federal Facility Agreement and Consent Order, Appendix I.

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RPP-RPT-27406
Revision 1

DEMONSTRATION RETRIEVAL DATA REPORT FOR SINGLE-SHELL TANK 241-S-112

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Date Published
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EXECUTIVE SUMMARY

Single-Shell Tank 241-S-112 Retrieval Demonstration Completed

The single-shell tank 241-S-112 (SST S-112) retrieval demonstration campaign began on September 26, 2003, and concluded on May 17, 2005. At the outset of the campaign, SST S-112 held an estimated 82,075 ft^3 of primarily saltcake waste. The demonstration campaign used a saltcake retrieval technology to remove an estimated 77,931 ft^3 of waste.

The saltcake retrieval technology retrieved waste from SST S-112 until the *Hanford Federal Facility Agreement and Consent Order*[1] (HFFACO), Milestone M-45-03C requirement to reach the limit of the technology's ability to remove waste was accomplished. At that point, approximately 95% of the saltcake waste was removed from SST S-112 and transferred to the double-shell tank (DST) system. Only hard heel waste comprising approximately 5% of the original volume remained.

The SST S-112 retrieval technology performed better than the past-practice sluicing retrieval baseline in three areas identified by M-45-03C. Demonstration sluicing showed the following:

- A fourfold improvement in retrieval water use efficiency.
- A lower potential for leak loss.
- Greater suitability for use in some potentially leaking tanks.

This Retrieval Data Report (RDR) presents data confirming that the demonstration technology's retrieval limit has been reached, states how other requirements and goals set forth in M-45-03C have been met or will be addressed, estimates the potential risk to human health from waste remaining in the tank, and addresses the path forward for the remaining hard heel waste. Table ES-1 summarizes the saltcake retrieval campaign's performance and accomplishments.

Table ES-1. SST S-112 Saltcake Retrieval Demonstration Data Summary.

Waste in tank at start of retrieval	614,000 gal = 82,075 ft^3 (100% at start)
Waste removed from SST S-112	583,000 gal = 77,931 ft^3 (95% removed)
Waste remaining after retrieval	31,000 gal = 4,144 ft^3 (5% residual)
Specific gravity (SpG) of initial waste solution	1.26
Peak day average SpG of waste solution	1.38
Average SpG of waste solution transferred on last day	1.05
Retrieval efficiency at start (lb waste/lb transferred) × 100	34.2%
Peak day average retrieval efficiency (lb waste/lb transferred) × 100	44.4%
Retrieval efficiency at finish (lb waste/lb transferred) × 100	6.6%
Retrieval efficiency compared to past-practice baseline	Fourfold improvement in retrieval water use efficiency over highest value observed during C-106 retrieval
Evidence of leaks during retrieval	No evidence of tank leaks.

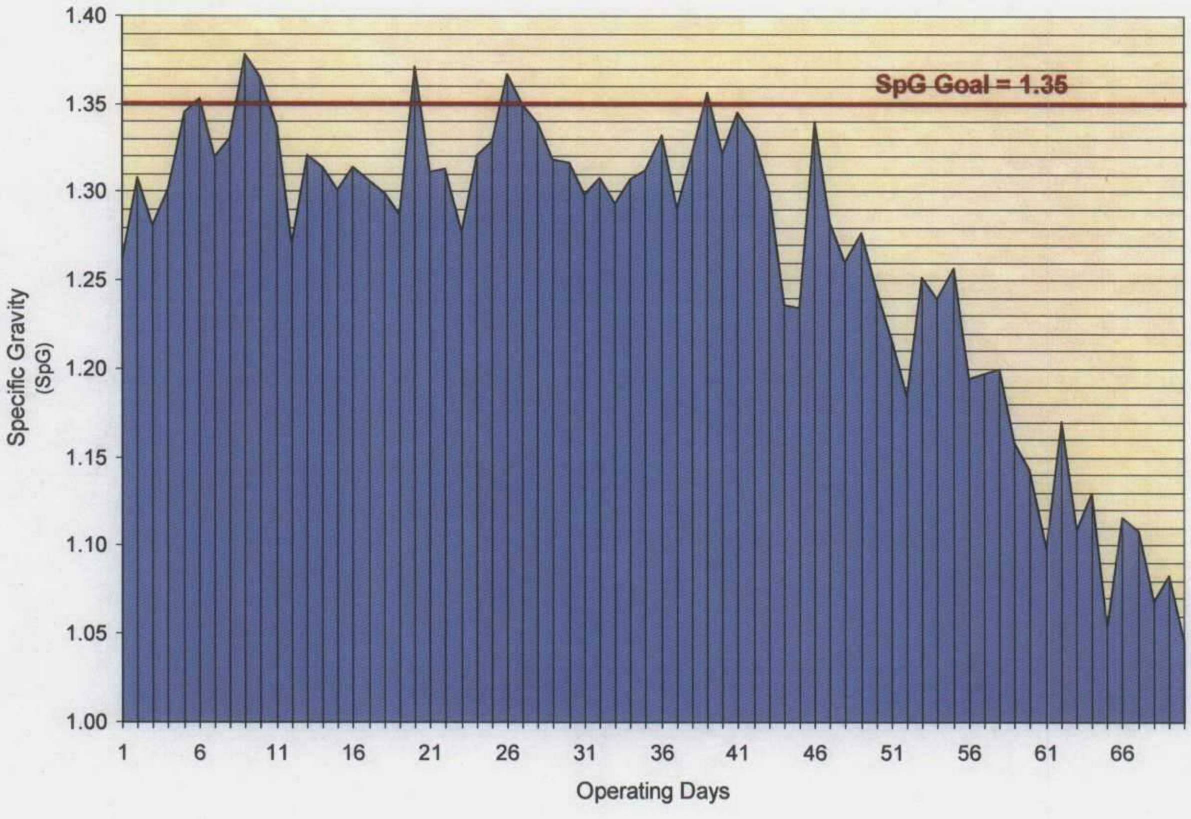
[1] (Ecology et al. 1989) also known as the Tri-Party Agreement.

Reaching the Limit of Technology

The technology used to retrieve saltcake waste from SST S-112 involves spraying the saltcake with water and allowing the water to soak into and dissolve the saltcake into a brine. High temperature water and water recirculation were used at times. After dissolution, the brine was pumped from SST S-112 and transferred to a DST.

Primary inputs for determining when the technology's retrieval limit had been reached included real-time measurements of the brine's specific gravity (SpG) and direct observation of the tank's interior. The SpG of the brine indicates the volume of waste being transferred from the tank. If the SpG is near 1.35, the retrieval technology is functioning efficiently. A decrease below 1.35 indicates that the percentage of dissolved saltcake in the brine has decreased and the technology is not efficiently removing waste (see Table ES-1). Figure ES-1 summarizes changes in SpG of the brine transferred from SST S-112 during the demonstration campaign.

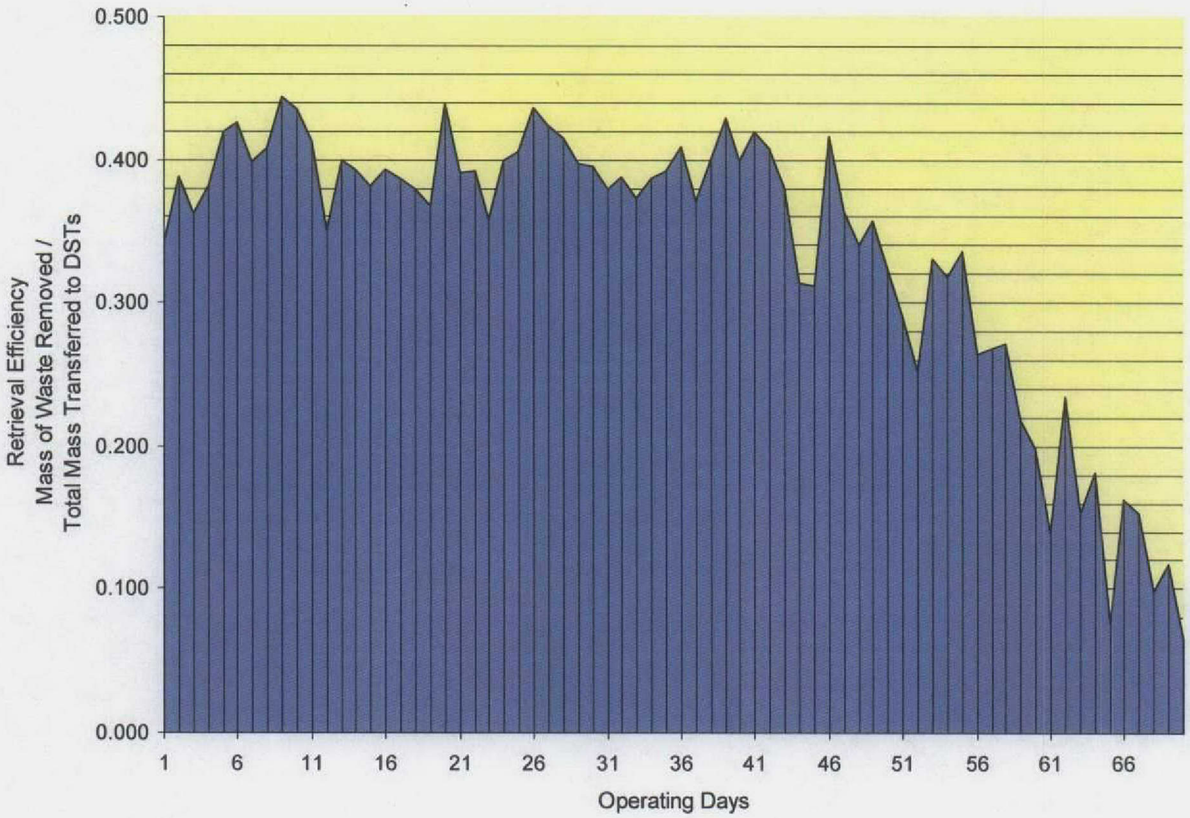
Figure ES-1. Average SpG of Brines Transferred per Operating Day.



Direct observation of conditions inside the tank, using a video camera, also aided in determining that the retrieval technology had reached its limit. The residual hard heel waste was observed in the bottom dish of SST S-112 as the last of the saltcake waste was removed. The inability of the demonstration technology to break the surface of the hard heel and remove the remaining waste was also observed.

Mass balances provided a gauge of retrieval efficiency and technological effectiveness that confirmed results of the SpG readings and direct observations. The difference between the mass of the solution pumped to the DSTs and the mass of water added to SST S-112 measures the mass of waste removed for each operation. Dividing the mass of removed waste by the total mass transferred to the DSTs results in an estimate of efficiency. A decline in efficiency over the course of a campaign indicates that a technology's limit is being reached. Figure ES-2 shows retrieval efficiency for SST S-112 as measured by mass balance.

Figure ES-2. Retrieval Efficiency per Operating Day.



During the saltcake retrieval demonstration, 77,931 ft^3 of waste was removed from SST S-112, but 4,144 ft^3 remains. No sampling or characterization was performed on waste still in the tank. Risk from remaining waste was estimated based on a 4,144 ft^3 waste volume and existing best-basis inventory (BBI) concentration data. The estimated cumulative risks do not meet performance objectives prescribed for closure of the SSTs, indicating that additional retrieval of SST S-112 will be necessary to reduce risks to meet performance objectives. Sampling after completion of retrieval is also necessary to improve accuracy of the inventory and risk estimates.

Path Forward

The M-45-03C requirement that waste be retrieved to the DST system to the limits of the technology selected has been met. Additional retrieval will be conducted at SST S-112 using an alternative technology to achieve the HFFACO M-45-00 retrieval criteria for volume of residual waste. On completion of retrieval, residual waste will be sampled. Characterization of the residual waste will be performed so that the risk assessment can be updated. Success of the additional retrieval will be evaluated against M-45-00 criteria and SST closure performance objectives. Lessons learned from the retrieval demonstration will be implemented as appropriate for future SST retrievals.

Recommendations for Further Action

Recommendations for further actions include the following:

Recommendation 1—Evaluate the deployment of the Remote Water Lance technology at SST S-112 to retrieve additional waste (expected completion in FY 2006) because the Remote Water Lance technology appears to be the best currently available alternative.

Recommendation 2—Select a technology, deploy the technology at SST S-112, and operate until the limits of technology are reached (expected completion no later than December 2007 in support of milestone M-45-13).

Recommendation 3—Follow the Appendix I process to complete retrieval at SST S-112 (expected completion no later than December 2007 in support of milestone M-45-13).

Recommendation 4—Implement lessons learned as appropriate during the second retrieval of SST S-112 and during the retrieval of other SSTs.

Conclusions

Table ES-2 measures the results of the SST S-112 saltcake waste retrieval technology demonstration against the requirements and goals established in HFFACO Milestone M-45-03C as follows:

Table ES-2. Measurement of SST S-112 Retrieval Demonstration Results Against M-45-03C. (2 sheets)

M-45-03C Requirement (R)/Goal (G)	Met	Addressed in Section	Conclusion
R: Complete full scale saltcake waste retrieval technology demonstration at SST S-112.	Yes	1.0	Demonstration was declared complete on 6/16/05.
R: Waste shall be retrieved to the DST system to the limits of the technology (or technologies) selected.	Yes	5.0	Proved that limits of technology have been reached as measured by water use and waste dissolution.
R: Must seek to improve on the past-practice sluicing baseline in the area of expected retrieval efficiency.	Yes	3.0	Retrieval efficiency improved fourfold.
R: Must seek to improve on the past-practice sluicing baseline in the area of leak loss potential.	Yes	4.0	An improved leak detection, monitoring, and mitigation plan was instituted during this campaign through design and procedure changes. No evidence of a leak occurred during retrieval demonstration.
R: Must seek to improve on the past-practice sluicing baseline in the area of suitability for use in potentially leaking tanks.	Yes	4.0	Saltcake waste retrieval technology is suitable for use in some potentially leaking tanks, but water volumes and soak times preclude its use in other potentially leaking tanks.

Table ES-2. Measurement of SST S-112 Retrieval Demonstration Results Against M-45-03C. (2 sheets)

M-45-03C Requirement (R)/Goal (G)	Met	Addressed in Section	Conclusion
G: Retrieval to safe storage of approximately 550 Ci of mobile, long-lived radioisotopes (in accordance with DOE BBI Data, 8/1/2000).	No	7.0	BBI update (1/1/2003) provides more accurate derivation of tank inventory. Data shows inventory of only 280 Ci at beginning of retrieval demonstration. This retrieval goal needs to be revisited during the next retrieval of SST S-112.
G: Retrieval to safe storage of approximately 99% of tank contents by volume (in accordance with DOE BBI Data, 8/1/2000).	No	6.0	95% of the inventory was removed when the limit of technology was reached. Continued retrieval using additional available technology is needed to meet this goal.

This RDR documents the condition, results, and accomplishments of the full-scale saltcake waste retrieval technology demonstration. The remaining waste volume in SST S-112 is greater than the HFFACO residual limit of 360 ft^3. A post-retrieval risk assessment using existing data is presented in this report. Lessons learned and an assessment of available technologies are also addressed for further retrieval of SST S-112 and future SST waste.

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Abbreviations and Acronyms

APF	all pathways farmer
BBI	best-basis inventory
BCR	Baseline Change Request
CASRN	Chemical Abstracts Service Registry Number
CFR	Code of Federal Regulations
CH2M HILL	CH2M HILL Hanford Group, Inc.
COPC	constituents of potential concern
DOE	U.S. Department of Energy
DST	double-shell tank
Ecology	Washington State Department of Ecology
EDE	effective dose equivalent
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESP	Environmental Simulation Program
HDW	Hanford Defined Waste
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HI	Hazard Index
HIHTL	hose-in-hose transfer line
HTWOS	Hanford Tank Waste Operations Simulator
ILCR	Incremental Lifetime Cancer Risk
LDMM	leak detection, monitoring, and mitigation
MCL	maximum contaminant level
MLDUA	modified light-duty utility arm
MTCA	Model Toxic Control Act
PCB	polychlorinated biphenyl
RDR	Retrieval Data Report
REDOX	reduction-oxidation (Fuel Reprocessing Facility in Building 202S at Hanford)
SST	single-shell tank
TODWD	target organ drinking water dose
TSR	Technical Safety Requirements
TWRWP	tank waste retrieval work plan
WAC	Washington Administrative Code
WMA	Waste Management Area

Units

Ci	curie
ft	foot
ft^3	cubic foot

g	gram
gal	gallon
gpm	gallons per minute
in.	inch
kg	kilogram
kgal	kilogallon
kL	kiloliter
L	liter
ml	milliliter
mrem	millirem
pCi	picocurie
SpG	specific gravity
yr	year

1.0 INTRODUCTION AND BACKGROUND

The *Hanford Federal Facility Agreement and Consent Order* (HFFACO), also known as the Tri-Party Agreement (Ecology et al. 1989), Milestone M-45-00 requires the U.S. Department of Energy (DOE) to retrieve waste from all single-shell tanks (SST) at the Hanford Site. The HFFACO also contains specific demonstration requirements for certain tanks.

SST 241- S-112 (SST S-112) is one of twelve 100-series SSTs constructed to store waste in S Farm. The S Farm is part of Waste Management Area (WMA) S-SX on the Hanford Site. The HFFACO Milestone M-45-03C requires DOE to complete a saltcake waste demonstration retrieval at SST S-112. The waste in SST S-112 is to be retrieved to the limit of the selected technology and the selected technology must seek to improve on the expected efficiency, leak loss potential, and suitability for deployment in potentially leaking tanks shown in the past-practice sluicing baseline. This Retrieval Data Report (RDR) describes the retrieval demonstration conducted for SST S-112.

Please note that source, special nuclear material, and byproduct materials, as defined in the *Atomic Energy Act of 1954* (AEA), as amended, are regulated at DOE facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts that, under the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned facilities. To the extent that this RDR document provides data or discussions about materials regulated by the AEA, that information is provided for informational purposes only.

1.1 PURPOSE AND SCOPE

This report documents the performance of the retrieval system, presents data confirming that the completed retrieval meets the limits of the demonstration technology's capacity to retrieve waste, summarizes the potential risk to human health from waste remaining in the tank, and addresses the path forward for the remaining hard heel waste. The information presented in this RDR provides information required by Section 2.1.7 of Appendix I to the HFFACO and details SST S-112 retrieval actions through the completion of the saltcake waste retrieval demonstration. A second technology is being planned to attempt retrieval of the remaining SST S-112 waste. When SST S-112 retrieval is completed, a final RDR will be submitted to document compliance with M-45-00 retrieval criteria or an exception to retrieval criteria in accordance with HFFACO Appendix H will be submitted.

1.2 HISTORY

Construction of SST S-112 began in 1950 and was completed in 1951. SST S-112 received waste from the reduction-oxidation (REDOX) complex from 1952 through 1957. Evaporator bottoms and recycling streams from the 242-S Evaporator-Crystallizer were added to the tank in 1973 and 1974. Some supernatant was removed from SST S-112 and the tank was removed from service in 1974. The majority of remaining supernatant was jet-pumped in 1978. The tank was declared stabilized in 1979 and partially isolated in 1982. No unplanned releases associated with SST S-112 are listed in the Waste Information Data System.

The SST S-112 retrieval demonstration campaign began on September 26, 2003, and concluded on May 17, 2005. During the campaign, 77,931 ft^3 of waste were removed from S-112.

1.3 REGULATORY REQUIREMENTS

The HFFACO Milestone M-45-00 provides in part:

> Closure will follow retrieval of as much tank waste as technically possible, with tank waste residues not to exceed 360 cubic feet (cu. ft.) In each of the 100 series tanks, ... or the limit of waste retrieval technology capability, whichever is less. If the DOE believes that waste retrieval to these levels is not possible for a tank, then DOE will submit a detailed explanation to EPA and Ecology explaining why these levels cannot be achieved, and specifying the quantities of waste that the DOE proposes to leave in the tank. The request will be approved or disapproved by EPA and Ecology on a tank-by-tank basis.

The HFFACO Milestone M-45-03C provides

> Complete full scale saltcake waste retrieval technology demonstration at single-shell tank S-112. Waste shall be retrieved to the double-shell tank (DST) system to the limits of the technology (or technologies) selected. Selected saltcake retrieval technology (or technologies) must seek to improve upon the past-practice sluicing baseline in the areas of expected retrieval efficiency, leak loss potential, and suitability for use in potentially leaking tanks.
>
> Goals of this demonstration shall include the retrieval to safe storage of approximately 550 Ci of mobile, long-lived radioisotopes and 99% of tank contents by volume (per DOE best-basis inventory data, 8/01/2000).

Section 2.1.7 of Appendix I to the HFFACO Action Plan provides

> 2.1.7 Retrieval Data Report
>
> Once DOE has completed the retrieval actions described in the Tank Waste Retrieval Work Plan (TWRWP), DOE will either complete the RDR and then submit it to Ecology within 120 days, or a request for exception to retrieval criteria per Agreement Appendix H. The Appendix H option is only applicable for SSTs.
>
> At a minimum, DOE's RDR will include
>
> - Residual tank waste volume measurement, including associated calculations.
> - The results of residual tank waste characterization.
> - Retrieval technology performance documentation.
> - DOE's updated post-retrieval risk assessment.
> - Discussion of feasibility / viability of other available retrieval technologies, the feasibility of developing additional retrieval technologies, associated detailed cost estimates and amount of additional waste that could be removed.
> - Opportunities and actions being taken to refine or develop tank waste retrieval technologies, based on lessons learned.

- LDMM monitoring and performance results.
- DOE's recommendation for further action and proposed schedule(s).

Data from this report will be used by Ecology and DOE in making WMA-, tank- and component-specific closure decisions. Single or multiple tank and component actions will be included in this report as appropriate.

1.4 PRE-RETRIEVAL CONDITIONS

This section summarizes the physical circumstances of the tank, the ancillary equipment used during retrieval, and the waste residing in the tank when retrieval began.

1.4.1 SST S-112 Description

SST S-112 is 75 ft in diameter, with a maximum operating height of 23.6 ft, an overall height of approximately 36.6 ft, and an operating capacity of 758,000 gal. The structure consists of a steel liner inside a reinforced-concrete shell with an asphaltic membrane between the liner and shell. The top of the tank sits approximately 10 ft below grade. Allowing space for footings and other construction requirements, the SST S-112 base is about 45 to 47 ft below the ground surface. An ENRAF™[1] gauge installed in SST S-112 is available to measure waste levels in the tank. Figure 1-1 presents a generalized profile view of a 100-series tank such as SST S-112.

1.4.2 Ancillary Equipment Providing Access to SST S-112

One pump pit, 12 risers, and a hatchway penetrate the SST S-112 dome, providing access to the interior of the tank. Four of the risers, R-1, R-5, R-6, and R-13, access the tank through the pump pit. The pit and the other risers extend from the tank roof to slightly above grade. Figure 1-2 provides a top-down view of SST S-112 and includes the pit, risers, and hatchway. Table 1-1 provides basic information on the SST S-112 risers and hatchway before retrieval began.

1.4.3 Waste Description and Conditions

The volume of waste in SST S-112 at the start of retrieval consisted of approximately 614,000 gal of waste. Laboratory testing of SST S-112 core samples showed that greater than 99% of the waste was soluble in water. Waste recovered from SST S-112 was scheduled to be transferred to DST 241-SY-101 and SY-102. Table 1-2 provides August 1, 2000, and January 1, 2003, summary best-basis inventory (BBI) information on SST S-112 waste before retrieval operations began. The former BBI represents the basis for the HFFACO Milestone M-45-03C goal: "...retrieval to safe storage of approximately 550 curies of mobile, long-lived radioisotopes...(per DOE best-basis inventory data, 8/01/2000)." The latter BBI represents the updated inventory at the start of SST S-112 retrieval demonstration.

Section 7.5 provides a comprehensive list of constituents in the SST S-112 chemical and radionuclide inventory.

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[1] ENRAF™ is a registered trademark of Enraf B. V., Delft, The Netherlands.

Figure 1-1. 100-Series Tank – Cutaway View.

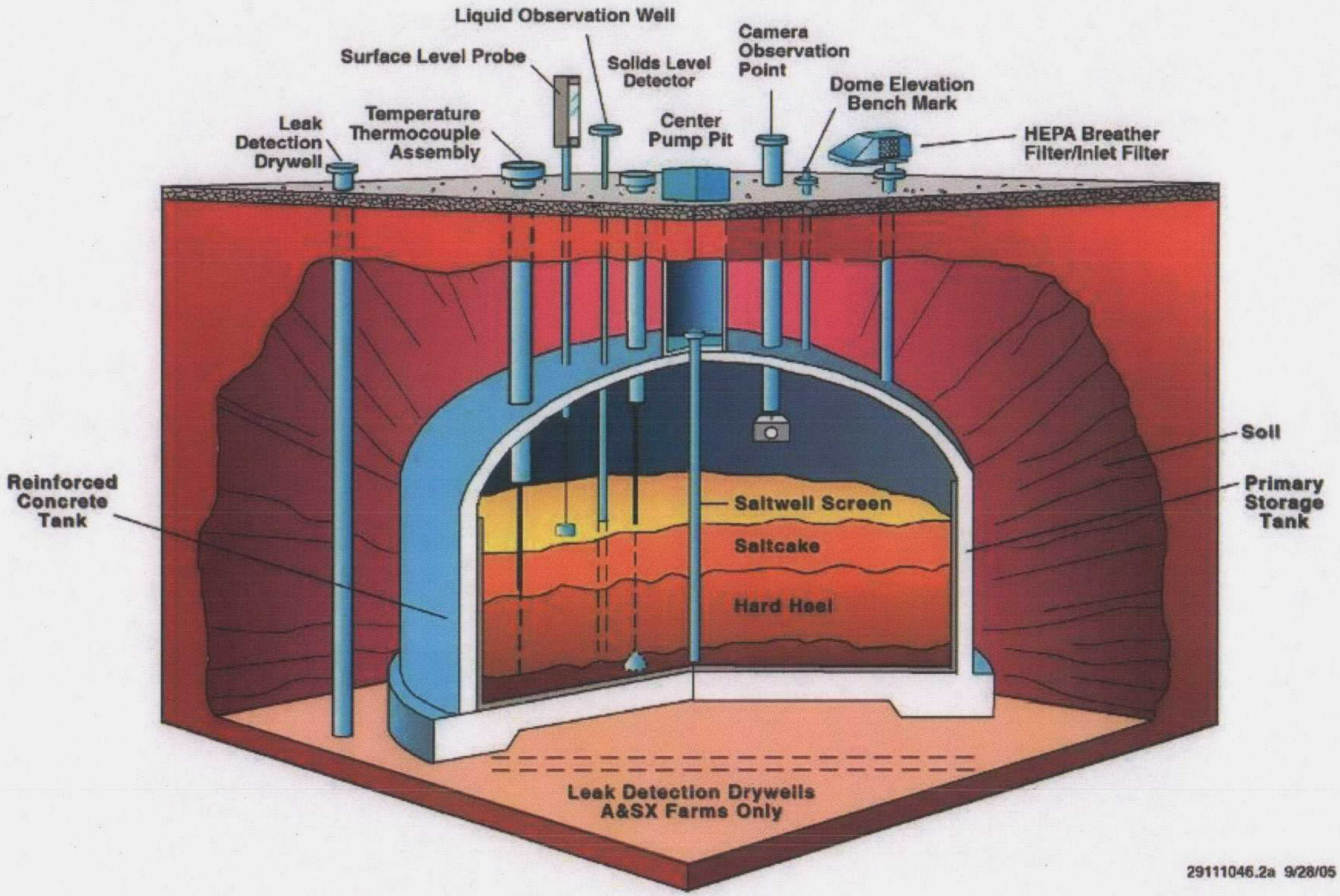


Figure 1-2. Configuration of SST S-112 and Adjacent Facilities.

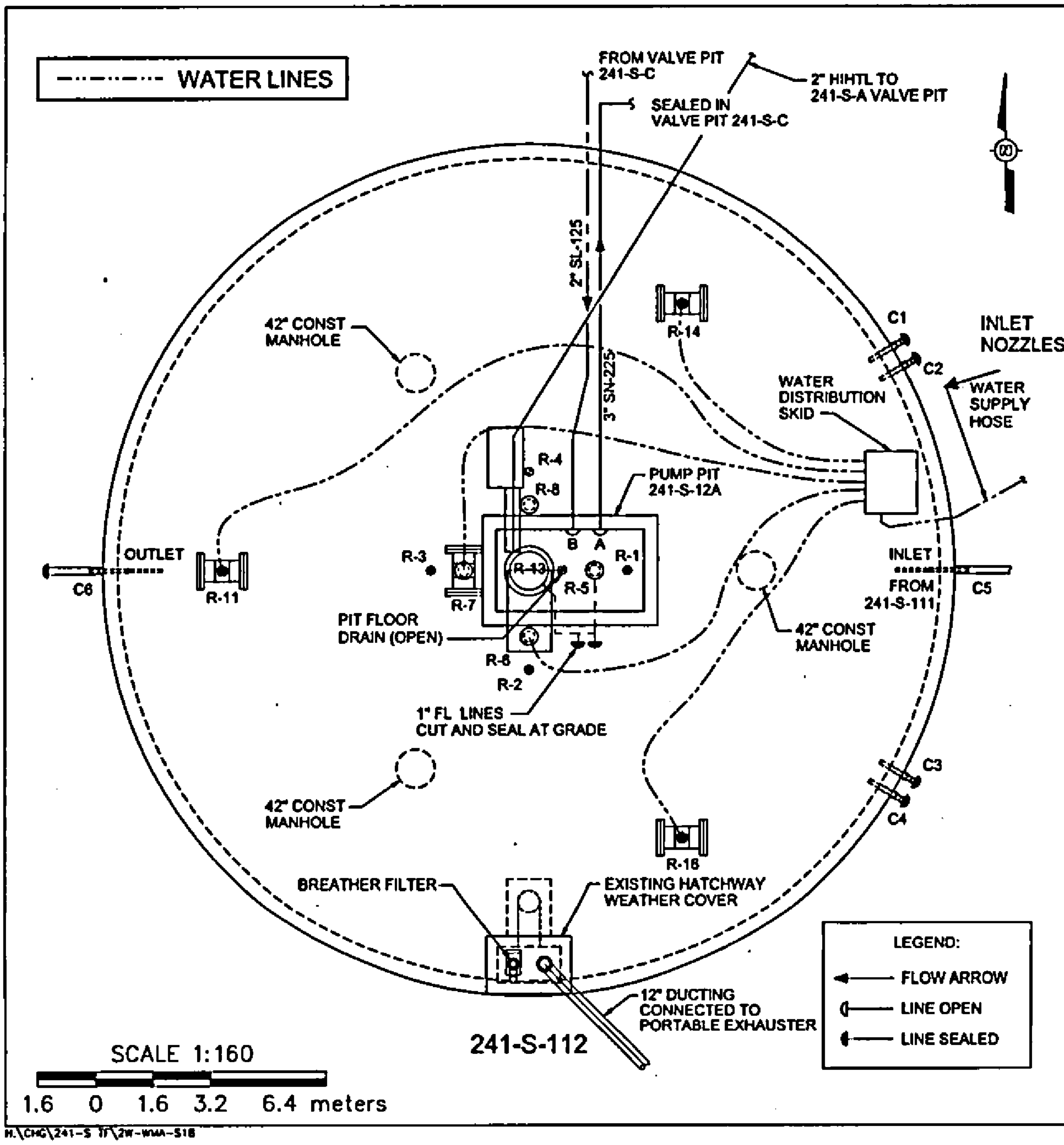


Table 1-1. Tank 241- S-112 Pre-Retrieval Riser and Hatchway Descriptions.

Riser ID	Minimum Diameter (in.)	Location	Description	Pre-Retrieval Status/Use	Access
R1	4	Pump pit	3-in. connector nozzle	Liquid transfer	Inside pit
R2	4	South of pump pit	Spare	Spare	Above grade
R3	4	West of pump pit	ENRAF 854 ATG level gauge	Measure waste level	Above grade
R4	4	North of pump pit	Temperature probe	Measure temperature	Above grade
R5	12	Pump pit	Saltwell pump	Pump waste	Inside pit
R6	12	Pump pit	Observation port	Observation	Above grade
R7	12	West of pump pit	Ventilation	Ventilation	Above grade
R8	12	North of pump pit	Liquid observation well	Observation	Above grade
R11	4	West of pump pit	Spare	Spare	Above grade
R13	42	Pump pit	Slurry distributor	Slurry transport	Inside pit
R14	4	North of pump pit	Breather filter	Remove airborne contaminants	Above grade
R16	4	South of pump pit	Sludge MEAS port	Sludge	Above grade
Hatchway	64	South of pump pit	Weather-covered	General access	Above grade

Note: Primary reference sources for above data are H-14-104176, *Waste Transfer Piping Diagram 200 West Area*, October 2003, and H-2-73191, *Piping Waste Tank Isolation Tk 24-S-112*, April 2002.

Table 1-2. SST S-112 Summary Best-Basis Inventory.

SST S-112 Constituent	8-1-00 Best-Basis Inventory	1-1-03 Best-Basis Inventory (inventory at start of retrieval)
Saltcake	517,000 gal	608,000 gal
Sludge	6,000 gal	6,000 gal
Retained gas	0 gal	0 gal
Total waste	523,000 gal	614,000 gal
Drainable interstitial liquid	74,000 gal	66,000 gal
Mobile, long-lived isotopes (^{79}Se, ^{99}Tc, ^{14}C, ^{129}I, uranium isotopes)	555 Ci	280 Ci
Total isotopes	1,583,000 Ci	683,000 Ci

1.5 DOCUMENT STRUCTURE

This report is organized as follows:

- **Section 1,** *Introduction and Background,* discusses the purpose and scope of the SST S-112 retrieval, presents requirements applicable to the retrieval and this report, describes the tank and certain associated equipment, summarizes the operating history and in-tank conditions when retrieval began, and outlines the report structure.
- **Section 2,** *Retrieval System Description,* describes retrieval system design and operation, lists major retrieval system components, depicts the retrieval process, and presents a retrieval chronology.
- **Section 3,** *Retrieval System Performance,* evaluates how well the retrieval system performed.
- **Section 4,** *Leak Detection, Monitoring, and Mitigation* (LDMM) describes LDMM methods and procedures, presents an LDMM chronology for SST S-112 retrieval, summarizes LDMM results, and indicates potential process improvements.
- **Section 5,** *Limits of Technology,* reports the method and findings used to determine that waste was recovered to the limit of the retrieval technology.
- **Section 6,** *Tank Volume Measurement,* describes the method for determining the volume of residual waste in the tank and presents results of the volume measurement process.
- **Section 7,** *Residual Waste Inventory and Risk Assessment,* describes the BBI derivation of waste remaining in SST S-112 on completion of the retrieval demonstration and summarizes the potential risk to human health from SST S-112 residual waste. The section identifies and discusses constituents of potential concern in the waste, describes the effects of retrieval and closure on long-term risk, presents expected cumulative health effects of source terms, relates calculated risk to residual waste volume, and summarizes overall conclusions of the risk assessment.
- **Section 8,** *Additional Available Technologies,* identifies other technologies considered for retrieving waste from SST S-112. The section describes available and future technologies and alternative retrieval scenarios, evaluates alternative methods, and assesses the utility of deploying additional technologies in SST S-112.
- **Section 9,** *Recommendations,* discusses recommendations for future actions associated with SST S-112 retrieval and potential impacts on retrieval and closure schedules.
- **Section 10,** *Conclusions,* measures demonstration results against HFFACO Milestone M-45-03C.
- **Section 11,** *References,* contains references for material cited in the report.

Table 1-3 presents a crosswalk of the HFFACO, Appendix I, Section 2.1.7, requirements and the related sections of this RDR that address each requirement.

Table 1-3. Crosswalk of HFFACO Appendix I, Section 2.1.7, Requirements and Corresponding Retrieval Data Report Sections.

Section 2.1.7 Requirements	RDR Section
Residual tank waste volume measurement, including associated calculations	6.0
Residual tank waste characterization data and results	7.0
Retrieval technology performance documentation	3.0, 5.0
An updated post-retrieval risk assessment	7.0
Discussion of feasibility and viability of other available retrieval technologies, the feasibility of developing additional retrieval technologies, associated detailed cost estimates and amount of additional waste that could be removed	8.0
Opportunities and actions being taken to refine or develop tank waste retrieval technologies, based on lessons learned	8.0
LDMM monitoring and performance results	4.0
DOE's recommendation for further action and proposed schedules	9.0

2.0 RETRIEVAL SYSTEM DESCRIPTION

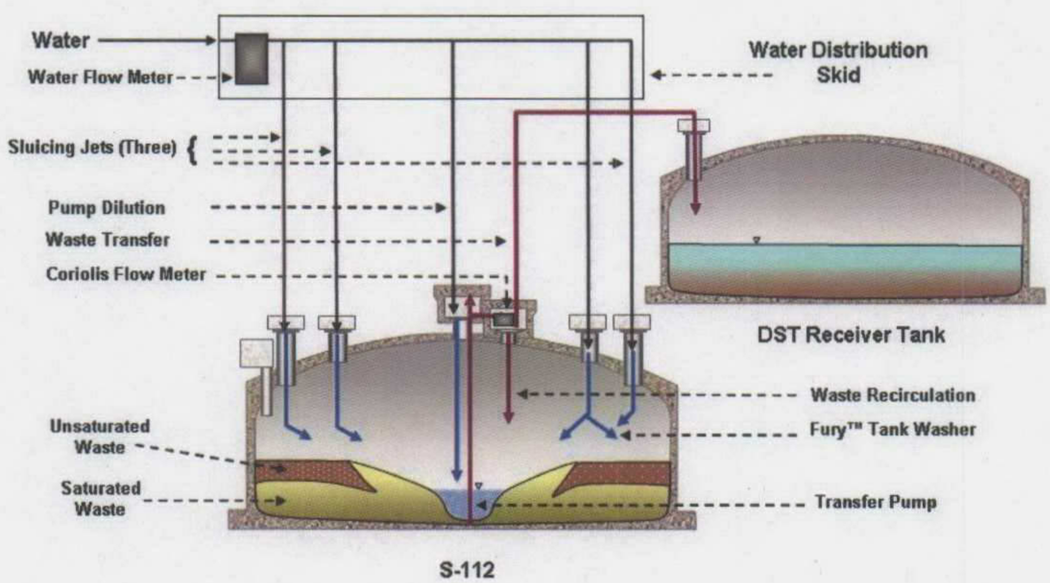
2.1 BASIS

The SST S-112 retrieval system was designed and constructed in accordance with RPP-7825, *Single-Shell Tank S-112 Full Scale Saltcake Waste Retrieval Technology Demonstration Functions and Requirements*. The functions and requirements document is the predecessor to the TWRWP now prescribed in Appendix I to the HFFACO. The system was operated in accordance with RPP-15085, *Process Control Plan for Saltcake Dissolution Retrieval Demonstration in Tank 241-S-112*.

2.2 OVERVIEW

The waste retrieval method for SST S-112 was saltcake dissolution, a process by which the soluble components of the waste are mobilized by dissolution and the resulting brine pumped out to a DST. The retrieval system is shown in Figure 2-1.

Figure 2-1. SST S-112 Saltcake Waste Retrieval System.



2.2.1 Water Distribution System

Water was introduced to the tank through four water distribution devices and a pump dilution line. The water distribution devices include three sluicing jets and a Fury™[1] Tank Washer. The sluicing jets have nozzles that can be remotely adjusted to direct the water stream. This improved waste dissolution through physical erosion of the waste as compared to water submersion only. The Fury Tank Washer was a self-indexing tank washer device capable of 360° rotation. The dilution water was used to flush the pump screen and maintain the specific gravity (SpG) of the brine solution at or below the target value of 1.35.

[1] Fury™ is a registered trademark of Chemdet, Inc., Port Washington, New York.

2.2.2 Waste Solution Removal System

The waste solution removal system was designed for the brine to pool in the center of the tank where it can be pumped via a hose-in-hose transfer line (HIHTL) to the DST. The pump had a capacity of approximately 90 gpm. Pump operation was integrated with water addition to manage the liquid level in the tank. The pump was located as close to the tank bottom as possible to maximize retrieval recovery. Brine could also be recirculated through an open riser in the pump pit.

2.3 RETRIEVAL SYSTEM INSTRUMENTATION

Material balance calculations were used to measure system performance, retrieval progress, leak detection monitoring, and final waste inventories. Data for these calculations are obtained from various instruments and include dissolution water flow rates and durations, video (for pool and waste volume estimation), dilution water temperature and flow rate, product stream flow rate, and density and liquid levels in the SST and DST.

Water usage was measured and recorded using a flow meter on the supply line to the water distribution system, which consisted of four water distribution devices and the dilution water line. Video recorded through closed-circuit television was viewed by operators and process engineers for qualitative volume estimates. Product (brine) stream volumetric flow rates and density were measured using a Micro Motion® Coriolis[2] device. Mass flow rate was calculated using volumetric flow rate and density measurements from the Coriolis device. Liquid levels were measured in the SST and DST using an ENRAF-Nonius[3] Series 854 servo tank gauge. The gauge was installed in a stilling well which allowed it to measure the interstitial liquid.

2.4 ENVIRONMENTAL CONTROLS

External letter AIR 03-209, *Notice of Construction Approval for Installation and Operation of Waste Retrieval Systems in Single-Shell Tank (SST) 241-S-112*, and RPP-7825, *Single-Shell Tank S-112 Full Scale Saltcake Waste Retrieval Technology Demonstration Functions and Requirements*, imposed a variety of environmental controls. These are summarized in Sections 2.4.1 through 2.4.4.

2.4.1 Exhauster Operation

SST S-112 headspace was ventilated with a portable exhauster whenever the transfer pump was operated or the total water addition rate exceeded 80 gpm. Active ventilation was required by AIR 03-209 and helped to reduce the headspace humidity, preventing or reducing fog formation, and reduce the headspace concentration of flammable gas. The DST headspace was operated under negative pressure using the SY-Farm exhauster.

2.4.2 Corrosion Mitigation

The pH, temperature, and total solids content of the transferred tank waste were monitored and adjusted as necessary to ensure compliance with the Corrosion Mitigation Program for the DST.

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[2] Micro Motion® Coriolis is a registered trademark of Micro Motion, a division of Emerson Process Management, Boulder, Colorado.
[3] ENRAF-Nonius is a registered trademark of Enraf B. V., Delft, The Netherlands.

The corrosion mitigation program is further explained in RPP-18150, *Waste Compatibility Assessment of Tank 241-S-112 Retrieval Waste (SST-R-03-09) with Tank 241-SY-102 Waste.*

2.4.3 Leak Detection Monitoring and Mitigation

The leak detection and monitoring techniques used are discussed in Section 4.2.

2.4.4 Secondary Containment

Leakage from the primary HIHTL (inner hose) would be contained by the secondary confinement system (outer hose) and could be detected by leak detectors, material balance data, or radiological surveys. The secondary confinement system was designed to drain any fluid released from the primary hose to a common point for collection, detection, and removal.

3.0 RETRIEVAL SYSTEM PERFORMANCE

Saltcake retrieval in SST S-112 was a technology demonstration with requirements and goals outlined in the HFFACO. The HFFACO Milestone M 45-03C requires that the "selected saltcake retrieval technology (or technologies) must seek to improve upon the past-practice sluicing baseline in the areas of expected retrieval efficiency, leak loss potential, and suitability for use in potentially leaking tanks."

The milestone also states that the "Goals of this demonstration shall include the retrieval to safe storage of approximately 550 curies of mobile, long-lived radioisotopes and 99% of tank contents by volume (per DOE BBI data, 8/01/2000)."

This section evaluates the performance of the retrieval technology demonstration in light of retrieval efficiency. Improvements in the areas of leak loss potential and suitability for use in potentially leaking tanks are discussed in Section 4.0. Goals related to retrieval of mobile, long-lived isotopes and tank contents by volume are addressed in Sections 7.0 and 6.0, respectively. Process data used to evaluate retrieval system performance are included in Tables 3-1 and 3-2. Volume and mass measurements in Tables 3-1 and 3-2 were taken from instrumentation described in Section 2.3.

3.1 RETRIEVAL PROCESS DESCRIPTION

The waste retrieval system described in Section 2.0 (Figure 2-1) was designed to mobilize and retrieve saltcake waste in SST S-112 and transfer it to a receiver DST in the SY tank farm. Water was used as a solvent to dissolve the saltcake and was preheated as necessary to increase the rate of dissolution and the amount of dissolved waste in the brine. The resulting brine solution was recirculated or pumped out to the receiver DST. Initially, retrieval progressed from the tank center outward.

The level of brine in the central cavity was maintained at a level that allowed drainage to flow through the saltcake toward the tank center. Operators maintained process efficiencies through monitoring the SpG. After soaking, the brine was recirculated to check the SpG. When the SpG reached 1.3, the transfer was initiated. As the SpG dropped to lower values or the brine was pumped completely out of the central cavity, the transfer was stopped. Recirculation, soak times, and water temperatures were increased as layers of "harder" or denser saltcake were encountered. Sluicing operations were coordinated with these soak times to physically break up the waste, entrain solids and soluble waste, and facilitate movement of the suspended solids toward the transfer pump intake.

3.2 RETRIEVAL SYSTEM PERFORMANCE

The S-112 retrieval system was operated 70 days over a 598-calendar-day period. Material balance was used during retrieval operations to estimate the residual waste in the tank per operating day and is also used to determine retrieval efficiency, limits of the technology (see further discussions in Section 5.0), and trends in retrieval performance. The basis for the material balance is a correlation between the specific gravity and mass of waste removed from SST S-112 (RPP-15085, Appendix B). This correlation was developed by laboratory analysis of two core samples of the waste. Figure 3-1 illustrates the SST S-112 demonstration retrieval system performance trend in terms of volume of waste remaining per operating day as determined by the material balance. It is not indicative of the actual waste volume in the tank on each day. An operating day is defined as a day in which a waste transfer was performed, regardless of number of hours operated.

Table 3-1. Material Balance Calculations During the SST S-112 Retrieval Campaign. (3 sheets)

Operating Day[a]	Date	Raw Water Added to S-112 (gal)	Volume Transferred to SY-Farm (gal)	Mass Transferred to SY-Farm (kg)	Average SpG of Waste Transferred	Average Mass of Waste Removed per Mass of Waste Transferred	Mass of Original S-112 Solute and Solids Removed (kg)
		ΔV_{H2O}[b]	ΔV[c]	ΔM[d]	SpG_{AVE}[e]	m_{AVE}[f]	$\Delta M_{S\&S}$[g]
0	9/27/03	0	0	0	--	0	0
1	9/28/03	3,631	3,478	16,619	1.26	0.342	5,686
2	9/30/03	60,997	68,703	340,278	1.31	0.388	132,040
3	10/1/03	75,429	86,200	418,223	1.28	0.362	151,490
4	10/2/03	49,400	61,741	304,079	1.30	0.381	115,900
5	11/8/03	12,472	22,813	116,177	1.35	0.420	48,679
6	11/9/03	62,917	81,406	417,083	1.35	0.426	177,800
7	11/17/03	47,852	63,125	315,535	1.32	0.399	125,728
8	11/18/03	21,068	27,344	137,734	1.33	0.408	56,031
9	11/19/03	14,824	16,563	86,398	1.38	0.444	38,395
10	11/20/03	9,994	16,563	85,624	1.37	0.436	37,302
11	11/25/03	44,026	59,233	299,914	1.34	0.414	124,064
12	12/17/03	1,719	2,768	13,317	1.27	0.351	4,677
13	12/18/03	46,646	57,145	285,770	1.32	0.399	113,881
14	12/19/03	21,920	26,286	130,766	1.31	0.393	51,431
15	12/20/03	21,554	27,941	137,633	1.30	0.381	52,441
16	12/21/03	19,321	22,141	110,173	1.31	0.394	43,291
17	12/22/03	14,566	25,438	125,848	1.31	0.387	48,645
18	12/23/03	20,095	28,750	141,426	1.30	0.380	53,669
19	12/26/03	30,346	22,500	109,673	1.29	0.368	40,378
20	12/28/03	28,081	30,781	159,755	1.37	0.440	70,187
21	12/29/03	19,085	17,344	86,100	1.31	0.391	33,647
22	12/30/03	1,249	7,031	34,953	1.31	0.392	13,719
23	12/31/03	17,421	16,250	78,589	1.28	0.358	28,140
24	1/9/04	9,920	33,125	165,719	1.32	0.400	66,283
25	1/14/04	52,652	98,906	497,578	1.33	0.406	202,183
26	1/20/04	30,552	22,500	116,429	1.37	0.437	50,831
27	1/22/04	27,035	28,125	143,697	1.35	0.423	60,854

Table 3-1. Material Balance Calculations During the SST S-112 Retrieval Campaign. (3 sheets)

Operating Day[a]	Date	Raw Water Added to S-112 (gal)	Volume Transferred to SY-Farm (gal)	Mass Transferred to SY-Farm (kg)	Average SpG of Waste Transferred	Average Mass of Waste Removed per Mass of Waste Transferred	Mass of Original S-112 Solute and Solids Removed (kg)
		ΔV_{H2O}[b]	ΔV[c]	ΔM[d]	SpG_{AVE}[e]	m_{AVE}[f]	$\Delta M_{S\&S}$[g]
28	1/27/04	38,202	46,250	234,514	1.34	0.415	97,383
29	2/2/04	30,456	30,625	152,902	1.32	0.398	60,793
30	2/3/04	419	25,625	127,735	1.32	0.396	50,547
31	2/6/04	348	33,594	165,186	1.30	0.379	62,630
32	2/10/04	12,954	24,531	121,472	1.31	0.388	47,102
33	2/12/04	22,491	5,625	27,537	1.29	0.374	10,289
34	2/17/04	31,914	45,156	223,497	1.31	0.387	86,535
35	2/20/04	5,775	31,250	155,265	1.31	0.392	60,835
36	2/26/04	25,047	13,282	67,002	1.33	0.410	27,438
37	2/27/04	17,905	25,001	122,127	1.29	0.371	45,301
38	6/11/04	12,464	15,091	75,544	1.32	0.401	30,270
39	6/12/04	27,255	29,001	148,970	1.36	0.429	63,926
40	6/15/04	10,840	11,776	58,915	1.32	0.400	23,566
41	6/19/04	6,584	18,515	94,286	1.35	0.420	39,596
42	6/28/04	179	18,723	94,286	1.33	0.408	38,426
43	6/30/04	593	8,566	42,181	1.30	0.381	16,068
44	7/2/04	8,548	10,432	48,838	1.24	0.314	15,346
45	12/11/04	20,338	16,015	74,851	1.23	0.312	23,348
46	12/13/04	976	20,556	104,306	1.34	0.416	43,397
47	12/19/04	30,716	5,483	26,629	1.28	0.364	9,681
48	12/26/04	10,017	21,628	103,200	1.26	0.340	35,117
49	12/30/04	10,232	9,615	46,487	1.28	0.358	16,627
50	1/2/05	539	10,646	50,171	1.24	0.323	16,225
51	1/6/05	0	21,327	98,171	1.22	0.290	28,509
52	1/7/05	10,560	5,313	23,820	1.18	0.252	6,009
53	1/12/05	10,006	10,441	49,465	1.25	0.331	16,354
54	1/16/05	10,004	9,134	42,880	1.24	0.318	13,639
55	1/26/05	7,397	16,836	80,103	1.26	0.336	26,946

Table 3-1. Material Balance Calculations During the SST S-112 Retrieval Campaign. (3 sheets)

Operating Day[a]	Date	Raw Water Added to S-112 (gal)	Volume Transferred to SY-Farm (gal)	Mass Transferred to SY-Farm (kg)	Average SpG of Waste Transferred	Average Mass of Waste Removed per Mass of Waste Transferred	Mass of Original S-112 Solute and Solids Removed (kg)
		ΔV_{H2O}[b]	ΔV[c]	ΔM[d]	SpG_{AVE}[e]	m_{AVE}[f]	ΔM_{SAS}[g]
56	1/28/05	10,443	8,627	39,007	1.19	0.265	10,320
57	2/1/05	1,812	11,372	51,557	1.20	0.269	13,843
58	2/14/05	8,606	11,925	54,174	1.20	0.271	14,705
59	2/16/05	2,930	4,961	21,748	1.16	0.219	4,760
60	2/18/05	8,581	7,656	33,125	1.14	0.199	6,598
61	2/24/05	4,518	7,608	31,649	1.10	0.140	4,431
62	3/25/05	4,984	9,537	42,250	1.17	0.235	9,909
63	4/5/05	7,939	8,477	35,580	1.11	0.153	5,461
64	4/6/05	17,779	22,779	97,396	1.13	0.181	17,671
65	4/7/05	2,585	652	2,600	1.05	0.076	199
66	4/8/05	4,469	2,827	11,941	1.12	0.163	1,947
67	4/12/05	3,174	6,856	28,766	1.11	0.153	4,399
68	4/15/05	9,257	5,856	23,689	1.07	0.098	2,319
69	5/13/05	9,996	7,441	30,500	1.08	0.118	3,589
70	5/17/05	1,014	8,436	33,400	1.05	0.066	2,198

[a] An operating day is defined as a day in which a transfer from S-112 to the DST receiver tank took place.

[b] $\Delta V_{H2O} = V_{H2Of} - V_{H2Oi} + V_{H2Oadj}$

[c] $\Delta V = V_f - V_i + V_{adj}$

[d] $\Delta M = M_f - M_i + M_{adj}$

[e] $SpG_{AVE} = \Delta M/(\Delta V * 3.78541\ L/gal)$

[f] $m_{AVE} = 0.0160 - 3.0414 * SpG_{AVE} + 4.5934 * SpG_{AVE}^2 - 1.5680 * SpG_{AVE}^3$ (RPP-15085, Appendix B)

[g] $\Delta M_{SAS} = m_{AVE} * \Delta M$

Note: The subscript *f* indicates final, *i* indicates initial, and *adj* indicates adjustments for water additions or waste transfers not accounted for by totalizer measurements (e.g. reset totalizer, water added manually, or transfer line flush)

Table 3-2. Cumulative Values for Material Balance Calculations during the S-112 Retrieval Campaign. (3 sheets)

Operating Day[a]	Date	Total Raw Water Added to S-112 (gal)	Total Volume Transferred to SY-Farm (gal)	Total Mass Transferred to SY-Farm (kg)	Average SpG of Waste Transferred	Average Mass of Waste Removed per Mass of Waste Transferred	Total Mass of Original S-112 Solute and Solids Transferred (kg)	Estimated S 112 Waste Remaining (gal)
		$\Sigma\Delta V_{H2O}$[b]	$\Sigma\Delta V$[c]	$\Sigma\Delta M$[d]	SpG_{AVE}[e]	m_{AVE}[f]	$\Sigma\Delta M_{S\&S}$[g]	$V_{BBI} - \Sigma\Delta V_{S112}$[h]
0	9/27/03	0	0	0	--	0	0	614,000
1	9/28/03	3,631	3,478	16,619	1.26	0.342	5,686	612,810
2	9/30/03	64,628	72,181	356,897	1.31	0.386	137,726	586,151
3	10/1/03	140,056	158,380	775,120	1.29	0.373	289,216	554,927
4	10/2/03	189,457	220,121	1,079,199	1.30	0.375	405,116	531,395
5	11/8/03	201,929	242,934	1,195,377	1.30	0.380	453,795	521,850
6	11/9/03	264,846	324,340	1,612,460	1.31	0.393	631,596	487,153
7	11/17/03	312,698	387,465	1,927,995	1.31	0.394	757,324	462,024
8	11/18/03	333,766	414,809	2,065,729	1.32	0.395	813,354	450,939
9	11/19/03	348,590	431,371	2,152,127	1.32	0.397	851,749	443,579
10	11/20/03	358,584	447,934	2,237,751	1.32	0.398	889,051	436,364
11	11/25/03	402,610	507,167	2,537,665	1.32	0.400	1,013,115	411,861
12	12/17/03	404,329	509,935	2,550,982	1.32	0.400	1,017,793	410,889
13	12/18/03	450,975	567,080	2,836,752	1.32	0.400	1,131,673	388,161
14	12/19/03	472,895	593,366	2,967,518	1.32	0.400	1,183,104	377,823
15	12/20/03	494,449	621,307	3,105,151	1.32	0.399	1,235,545	367,191
16	12/21/03	513,770	643,448	3,215,324	1.32	0.399	1,278,836	358,502
17	12/22/03	528,336	668,886	3,341,172	1.32	0.398	1,327,481	348,672
18	12/23/03	548,431	697,636	3,482,598	1.32	0.397	1,381,151	337,767
19	12/26/03	578,777	720,136	3,592,271	1.32	0.397	1,421,529	329,483
20	12/28/03	606,858	750,917	3,752,026	1.32	0.399	1,491,715	315,962
21	12/29/03	625,943	768,261	3,838,126	1.32	0.398	1,525,363	309,184
22	12/30/03	627,192	775,292	3,873,079	1.32	0.398	1,539,082	306,424
23	12/31/03	644,613	791,542	3,951,668	1.32	0.398	1,567,222	300,605
24	1/9/04	654,533	824,667	4,117,387	1.32	0.398	1,633,504	287,356

Table 3-2. Cumulative Values for Material Balance Calculations during the S-112 Retrieval Campaign. (3 sheets)

Operating Day[a]	Date	Total Raw Water Added to S-112 (gal)	Total Volume Transferred to SY-Farm (gal)	Total Mass Transferred to SY-Farm (kg)	Average SpG of Waste Transferred	Average Mass of Waste Removed per Mass of Waste Transferred	Total Mass of Original S-112 Solute and Solids Transferred (kg)	Estimated S 112 Waste Remaining (gal)
		$\Sigma\Delta V_{H2O}$[b]	$\Sigma\Delta V$[c]	$\Sigma\Delta M$[d]	SpG_{AVE}[e]	m_{AVE}[f]	$\Sigma\Delta M_{S\&S}$[g]	$V_{BBI} - \Sigma\Delta V_{S112}$[h]
25	1/14/04	707,185	923,573	4,614,965	1.32	0.399	1,835,688	247,172
26	1/20/04	737,737	946,073	4,731,394	1.32	0.400	1,886,519	237,349
27	1/22/04	764,772	974,198	4,875,091	1.32	0.400	1,947,373	225,438
28	1/27/04	802,974	1,020,448	5,109,605	1.32	0.401	2,044,756	206,232
29	2/2/04	833,430	1,051,073	5,262,507	1.32	0.401	2,105,549	194,056
30	2/3/04	833,849	1,076,698	5,390,242	1.32	0.401	2,156,096	183,916
31	2/6/04	834,197	1,110,292	5,555,428	1.32	0.400	2,218,726	171,179
32	2/10/04	847,151	1,134,823	5,676,900	1.32	0.400	2,265,827	161,667
33	2/12/04	869,642	1,140,448	5,704,437	1.32	0.400	2,276,116	159,565
34	2/17/04	901,556	1,185,604	5,927,934	1.32	0.399	2,362,651	142,081
35	2/20/04	907,331	1,216,854	6,083,199	1.32	0.399	2,423,486	129,837
36	2/26/04	932,378	1,230,136	6,150,201	1.32	0.399	2,450,924	124,398
37	2/27/04	950,283	1,255,136	6,272,328	1.32	0.399	2,496,225	115,125
38	6/11/04	962,747	1,270,227	6,347,873	1.32	0.399	2,526,494	109,078
39	6/12/04	990,002	1,299,228	6,496,842	1.32	0.399	2,590,420	96,633
40	6/15/04	1,000,842	1,311,004	6,555,757	1.32	0.399	2,613,987	91,922
41	6/19/04	1,007,426	1,329,519	6,650,043	1.32	0.400	2,653,582	84,147
42	6/28/04	1,007,605	1,348,242	6,744,329	1.32	0.400	2,692,008	76,516
43	6/30/04	1,008,198	1,356,808	6,786,510	1.32	0.400	2,708,076	73,253
44	7/2/04	1,016,746	1,367,240	6,835,348	1.32	0.399	2,723,422	69,975
45	12/11/04	1,037,084	1,383,255	6,910,199	1.32	0.398	2,746,770	64,980
46	12/13/04	1,038,060	1,403,811	7,014,505	1.32	0.399	2,790,167	56,428
47	12/19/04	1,068,776	1,409,294	7,041,135	1.32	0.398	2,799,848	54,434
48	12/26/04	1,078,793	1,430,922	7,144,335	1.32	0.398	2,834,965	47,075
49	12/30/04	1,089,025	1,440,537	7,190,821	1.32	0.397	2,851,592	43,636
50	1/2/05	1,089,564	1,451,183	7,240,992	1.32	0.397	2,867,817	40,193
51	1/6/05	1,089,564	1,472,510	7,339,163	1.32	0.396	2,896,327	33,999

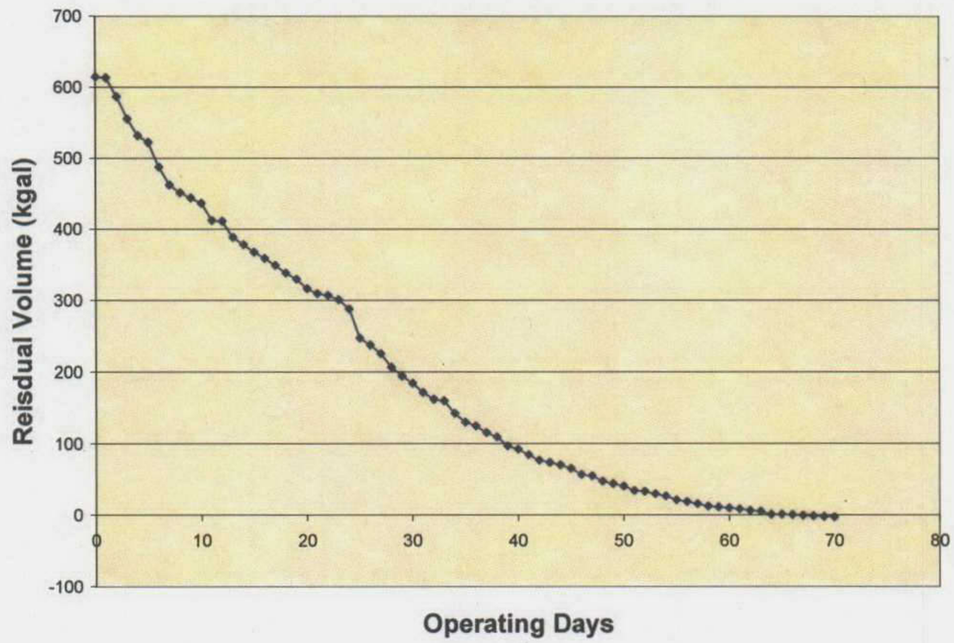
Table 3-2. Cumulative Values for Material Balance Calculations during the S-112 Retrieval Campaign. (3 sheets)

Operating Day[a]	Date	Total Raw Water Added to S-112 (gal)	Total Volume Transferred to SY-Farm (gal)	Total Mass Transferred to SY-Farm (kg)	Average SpG of Waste Transferred	Average Mass of Waste Removed per Mass of Waste Transferred	Total Mass of Original S-112 Solute and Solids Transferred (kg)	Estimated S 112 Waste Remaining (gal)
		$\Sigma\Delta V_{H2O}$[b]	$\Sigma\Delta V$[c]	$\Sigma\Delta M$[d]	SpG_{AVE}[e]	m_{AVE}[f]	$\Sigma\Delta M_{S\&S}$[g]	$V_{BBI} - \Sigma\Delta V_{S112}$[h]
52	1/7/05	1,100,124	1,477,823	7,362,983	1.32	0.395	2,902,336	32,659
53	1/12/05	1,110,130	1,488,264	7,412,448	1.32	0.395	2,918,690	29,207
54	1/16/05	1,120,134	1,497,398	7,455,328	1.32	0.394	2,932,329	26,302
55	1/26/05	1,127,531	1,514,234	7,535,431	1.31	0.394	2,959,275	20,638
56	1/28/05	1,137,974	1,522,861	7,574,438	1.31	0.393	2,969,596	18,356
57	2/1/05	1,139,786	1,534,233	7,625,995	1.31	0.392	2,983,439	15,302
58	2/14/05	1,148,392	1,546,158	7,680,170	1.31	0.392	2,998,144	12,065
59	2/16/05	1,151,322	1,551,119	7,701,917	1.31	0.391	3,002,905	10,979
60	2/18/05	1,159,903	1,558,775	7,735,042	1.31	0.390	3,009,503	9,454
61	2/24/05	1,164,421	1,566,383	7,766,691	1.31	0.389	3,013,933	8,389
62	3/25/05	1,169,405	1,575,920	7,808,940	1.31	0.389	3,023,842	6,153
63	4/5/05	1,177,344	1,584,397	7,844,520	1.31	0.388	3,029,303	4,852
64	4/6/05	1,195,123	1,607,176	7,941,916	1.31	0.385	3,046,973	719
65	4/7/05	1,197,708	1,607,828	7,944,516	1.31	0.385	3,047,172	669
66	4/8/05	1,202,177	1,610,655	7,956,457	1.30	0.385	3,049,119	208
67	4/12/05	1,205,351	1,617,511	7,985,223	1.30	0.384	3,053,518	-841
68	4/15/05	1,214,608	1,623,367	8,008,912	1.30	0.383	3,055,837	-1,414
69	5/13/05	1,224,604	1,630,808	8,039,411	1.30	0.382	3,059,426	-2,289
70	5/17/05	1,225,618	1,639,244	8,072,811	1.30	0.381	3,061,623	-2,844[i]

[a] An operating day is defined as a day in which a transfer from S-112 to the DST receiver tank took place.
[b] $\Sigma\Delta V_{H2O} = \Sigma(V_{H2Of} - V_{H2Oi} + V_{H2Oadj})$ where V_{H2O}= *Volume of water addition*
[c] $\Sigma\Delta V = \Sigma(V_f - V_i + V_{adj})$ *where V=Volume transferred to the receiver tank*
[d] $\Sigma\Delta M = \Sigma(M_f - M_i + M_{adj})$ *where M=Mass transferred to receiver tank*
Note: The subscript *f* indicates final, *i* indicates initial, and *adj* indicates adjustments for water additions or waste transfers not accounted for by totalizer measurements (e.g., reset totalizer, water added manually, or transfer line flush)

[e] $SpG_{AVE} = \Sigma\Delta M / \Sigma(\Delta V * 3.78541\ L/gal)$
[f] $m_{AVE} = 0.0160 - 3.0414*SpG_{AVE} + 4.5934*SpG_{AVE}^2 - 1.5680*SpG_{AVE}^3$ (RPP-15085, Appendix B)
[g] $\Sigma\Delta M_{S\&S} = m_{AVE}*\Sigma\Delta M$
[h] $V_{BBI} = 614$ *kgal*, $V_{S112} = \Delta M_{S\&S}/SpG_{AVE}/3.78541$ *L/gal*
[i] This value results from material balance calculations based on laboratory data (RPP-15085, Appendix B); this data is indicative of trends, not direct measurement of waste in the tank; see discussion in Section 3.2.

Figure 3-1. Residual Waste in SST S-112 According to Material Balance.[a]



[a] Figure 3-1 is indicative of process trends, not actual waste volume in SST S-112; see Section 3.2 for further discussion.

The BBI value of the waste remaining in SST S-112 is a better basis for indicating the actual waste volume through direct tank measurements. The final volume measurement indicated that about 31,000 gal of waste remained in SST S-112. Further discussions of the residual waste volume measurement are in Section 6.0.

Pre-retrieval goals of the system performance were developed through various planning documents (Table 3-3). Performance goals were used to evaluate the actual retrieval system performance following the campaign. Table 3-3 summarizes the key performance goals. Actual retrieval performance is discussed in terms of these goals.

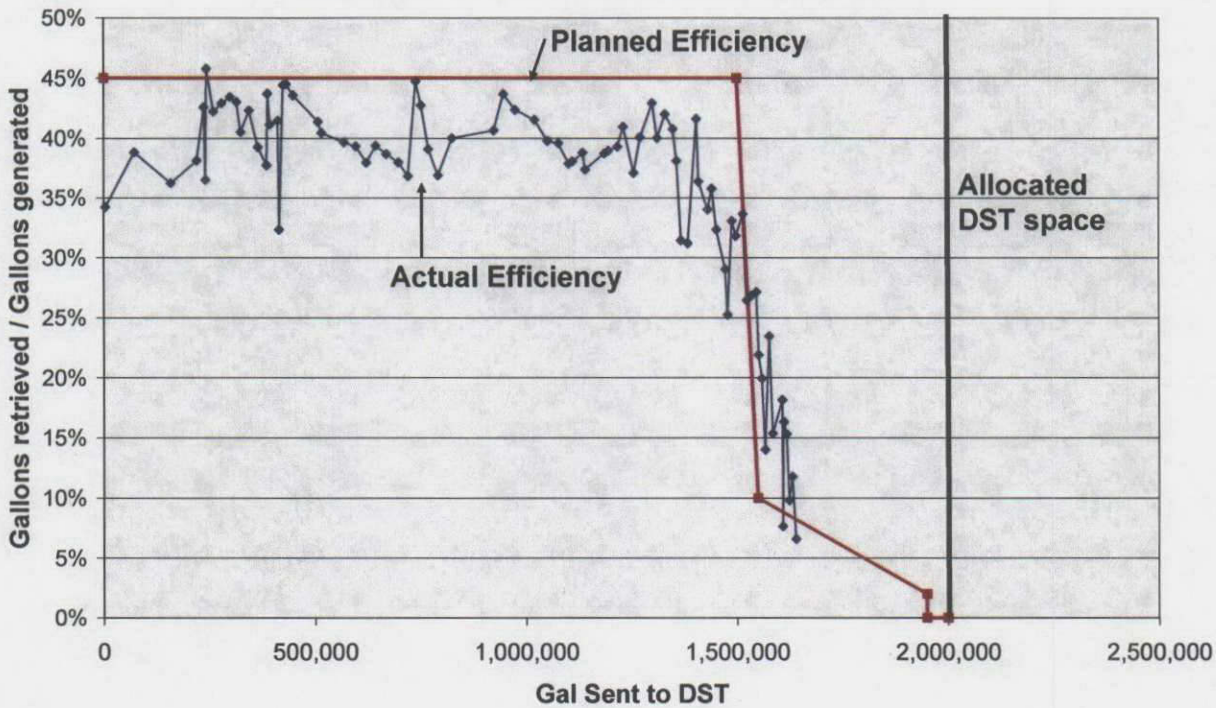
Table 3-3. System Performance Goals.

Measurement	Objectives	Source
Remaining tank waste residues (ft^3)	<360	Section 4.5, Page 4-2 of RPP-7825, *Single-Shell Tank S-112 Full Scale Saltcake Waste Retrieval Technology Demonstration Functions and Requirements*
Volume of waste retrieved (%)	99	Section 4.5, Page 4-2 of RPP-7825
Retrieval duration (days)	14-28	Section 5.2.1, Page 5-2 of RPP-7825
Retrieval efficiency[a]	0.45	Appendix B of RPP-15085, *Process Control Plan for Saltcake Dissolution Retrieval Demonstration in Tank 241-S-112*
Total water use (gal)	1,321,400	Page A-3, RPP-18694, *Tank S-112 Retrieval Process Flowsheet Calculation*

[a] Retrieval efficiency is defined as mass of waste retrieved (SST S-112 waste) per mass of waste transferred to the DST (waste plus water). This value is valid only for the first 1.5 million gal transferred to the DST.

Retrieval efficiency goals were developed using dissolution data for the waste in ST S-112 (Figure 3-2). Retrieval efficiency is defined as the mass of waste retrieved divided by the volume of waste and water transferred to the receiver tank. The Environmental Simulation Program (ESP) modeled the amount of saltcake that would readily dissolve into the brine throughout retrieval. This data agreed with data from laboratory dissolution performed on actual tank waste (RPP-15085, Appendix B). The ESP model predicted that the first 1.5 million gal of waste transferred to the receiver DST would have a concentration of 0.45 kg of original tank waste per transferred kg. The steep decline predicted toward the end of retrieval would be due to less available soluble saltcake waste remaining and the presence of insoluble sludge.

Figure 3-2. SST S-112 Retrieval Efficiency.



Waste was retrieved consistently near retrieval efficiency goals throughout the campaign, being approximately five percentage points lower than planned during the first 1.5 million gal transferred to the DST (Figure 3-2). In general, the actual efficiency followed the planned efficiency including the predicted steep decline in solubility at the end of retrieval. However, this decline in solubility was caused by dense layers of saltcake encountered at the bottom of the tank, not dwindling volumes of saltcake and insoluble sludge (hard heel).

The dense saltcake layer proved to be a challenge in part due to its lack of surface area. The rate of dissolution is proportional to the surface area of salt that the water contacts. The waste in the upper areas of the tank was porous and dissolved readily; the dense layers at the bottom of the tank were smooth surfaces with very few irregularities. Consequently, the water from sluicing jets skimmed the salt surface and was unable to cut grooves or break pieces off of the salt in the heel material. The dissolution slowed to the point that water use much larger than planned would have been necessary to retrieve the remaining waste.

The chemical process of dissolving the SST S-112 waste into water is endothermic; it absorbs heat from its environment. Additionally, the dissolution process is affected by temperature; the lower the temperature, the slower the reaction. Through the course of retrieval, salt dissolution and winter seasonal temperatures contributed to a lower tank waste temperature (Figure 3-3). It was also clear that the dissolution rate was becoming slower. To accelerate dissolution, heated water was added to the tank beginning June 10, 2004. This addition of heat stabilized the tank temperature (Figure 3-4). Sharp increases in temperature in Figures 3-3 and 3-4 indicate heated water additions.

Figure 3-3. SST S-112 Waste Temperature Before Heated Water.

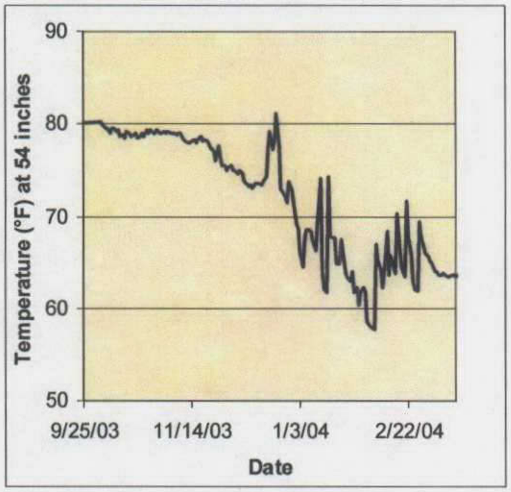
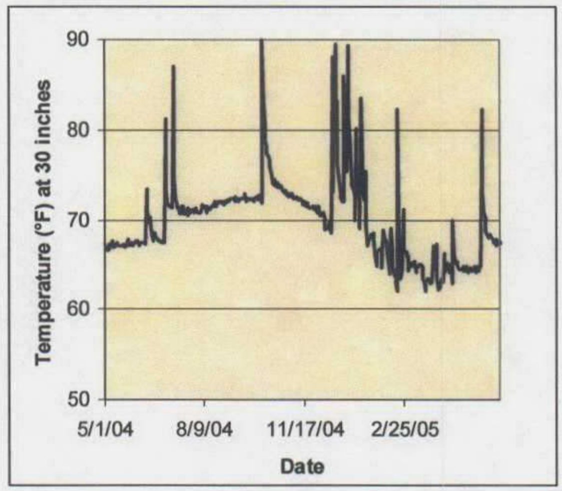


Figure 3-4. SST S-112 Waste Temperature After Heated Water.



Controlled volumes of water were used to dissolve and break up waste in SST S-112. In the early stages of retrieval, large quantities of water were used to treat the large quantity of saltcake in the tank. As retrieval progressed, slow dissolution produced smaller volumes of dense brine, less waste was transferred, and less water was used, as shown in Figure 3-5.

The planning basis for the duration of retrieval was a pump-limited rate, where dissolution achieves target density very quickly, and the pumping rate is the only limit on how quickly the tank can be emptied. The actual scenario was dissolution-limited, where the saltcake needed gradually longer times for recirculation or soaking to achieve the target density. As retrieval progressed, dissolution slowed, extending the predicted retrieval time from 22 operating days to 70 operating days (Figure 3-6).

Additionally, Figure 3-7 shows that retrieval performance was affected by a number of unpredicted outages related to general tank farm vapor issues, switching receiver DSTs, training, and other maintenance outages. The saltcake dissolution demonstration lasted longer than initially anticipated as a result of the unpredicted outages and the time required to dissolve saltcake waste. Although the technology can retrieve larger amounts of waste per volume transferred than other technologies, the time to achieve this may take longer.

Figure 3-5. Water Additions During SST S-112 Retrieval.

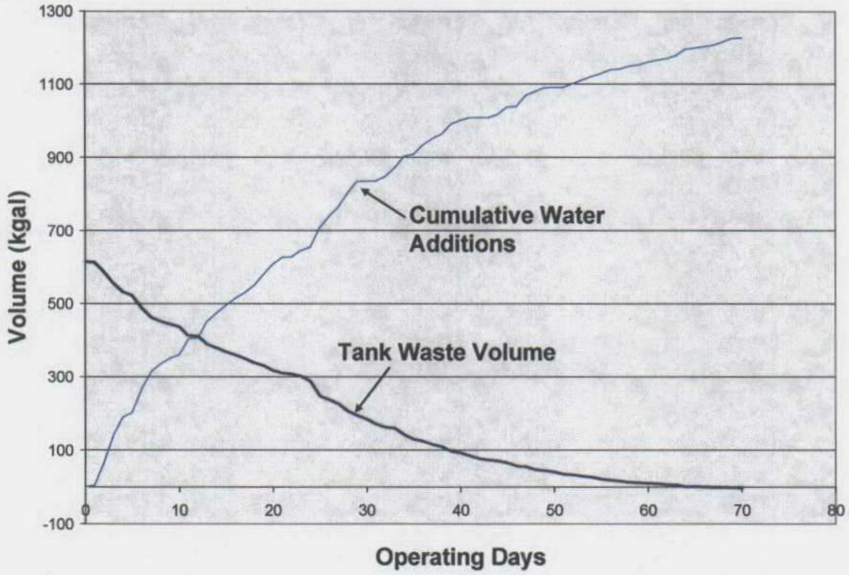
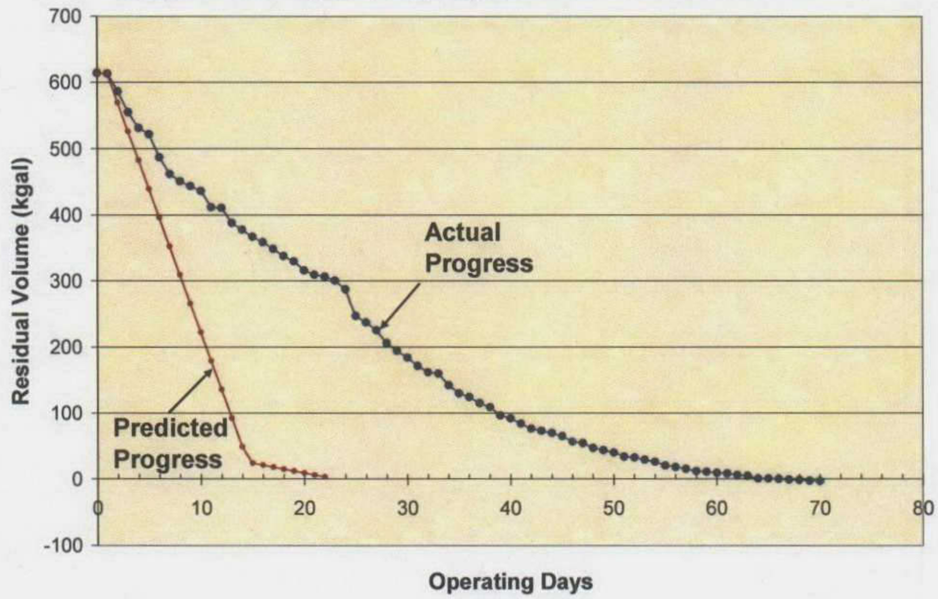


Figure 3-6. Operating Days to Retrieve SST S-112.



3.3 PREDICTED VERSUS ACTUAL RETRIEVAL PERFORMANCE

The retrieval data was used to evaluate the system's performance against the pre-retrieval objectives as shown in Table 3-3. Results are provided in Table 3-4. The system did not achieve expectations for water use, remaining tank waste residues, volume of waste retrieved, retrieval duration, or retrieval efficiency. Although the value for actual water use is lower than the objective, extrapolating the data for retrieval of the remaining volume of waste exceeds the water use goals. The performance curves in the previous section indicate that the demonstration system was affected by the behavior of the waste, which resulted in lower efficiencies than expected.

Figure 3-7. Retrieval Duration with Outages.

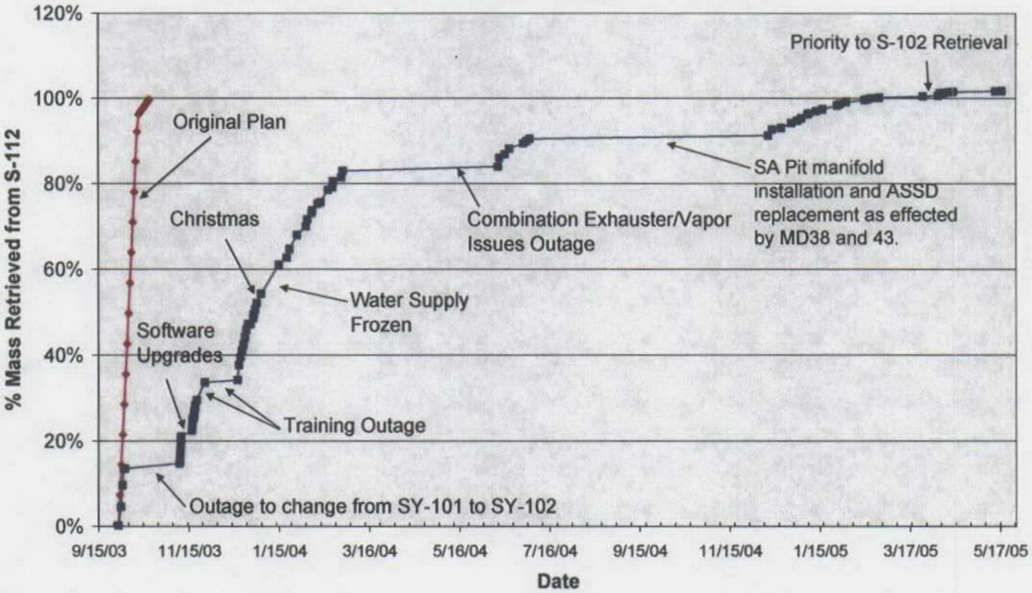


Table 3-4. Predicted and Actual Performance Indicators.

Measurement	Objective	Actual	Achieved Expectations?
Remaining tank waste residues (ft^3)	<360	4,144[a]	No
Volume of waste retrieved (%)	99	95[b]	No
Retrieval duration (days)	14-28	70[c]	No
Retrieval efficiency[d]	0.45	0.39[e]	No
Total water use (gal)	1,321,400	1,225,618[f]	No[g]

[a] Based on ENRAF level measurement.

[b] Calculated from 100% minus the residual volume (31 kgal) divided by the initial volume (614 kgal) 100% - (31/614)=95%

[c] Based on the number of days when a transfer of waste from SST S-112 to the receiver DST took place.

[d] Retrieval efficiency is defined as gal of tank waste retrieved (SST S-112 waste) per gal of tank waste transferred to the DST (waste plus water). This value is valid only for the first 1.5 million gal total waste transferred to the DST.

[e] Calculated from the average cumulative SpG of the waste after 1.5 million gal of waste transferred.

[f] See the last value in Table 3-2

[g] The total water use extrapolated through completion of retrieval is more than the predicted total water use.

In addition to basic evaluation of performance, the HFFACO's additional requirements for the SST S-112 Saltcake Dissolution Demonstration include improving "upon the past-practice sluicing baseline in the areas of expected retrieval efficiency." Past-practice sluicing was a process where water or recycled supernatant in large volumes were added to a tank to suspend the solid waste for transfer. During the W-320 sluicing campaign in SST C-106, the mass fraction of retrieved waste ranged from 0.0972 to 0.0035.

The SST S-112 retrieval demonstration technology adopted a modified sluicing approach using controlled volumes of water and a target SpG to improve retrieval efficiency. The average mass fraction of retrieved waste during the SST S-112 saltcake demonstration was 0.381, almost a factor of four greater than the best achieved by past-practice sluicing. The increased efficiency is mostly due to the dissolving nature of saltcake waste. More information regarding improvements upon past-practice sluicing in the area of LDMM is found in Section 4.0.

3.4 LESSONS LEARNED

Lessons learned were captured in July 2004 after about 80% of tank waste had been retrieved. These lessons learned are documented in RPP-20908, *Lessons Learned from the Tank 241-S-112 Waste Retrieval Project*. Selected lessons learned related to performance of the system are summarized here.

3.4.1 Waste Dissolution Assumptions

The waste dissolution rates were highly variable and dependent on properties of the various saltcake layers. Some layers permit dissolution of underlying layers, while others inhibit dissolution. Review of archived cores may assist in identifying problematic layers during the planning stages rather than in the field.

3.4.2 Waste Removal Strategy

Changes in waste behavior may dictate modifications to the waste removal strategy. For example, the original "mining strategy" of dissolving a hole in the center of the tank and working down steadily by blasting away at the side of this hole was changed when hard saltcake was encountered. The modified strategy involved steadily removing the whole hard surface layer.

3.4.3 Sluice Water Temperature and Pressure

The dissolution rate is directly proportional to temperature. Therefore, higher temperatures should lead to higher dissolution rates. Equipment such as water hoses and tank exhauster systems should be designed for as high a temperature as practical to permit greater sluicing water temperatures.

3.4.4 Optimization of Waste Dissolution Rate

Waste dissolution rates may be optimized by allowing more effective recirculation of brine. This could be accomplished by installing a movable discharge nozzle on the recirculation line, increasing discharge pressures, and balancing the waste pump-out rate with the fresh water input. Ideally a steady-state feed-and-bleed system would be established with a constant specific gravity.

3.4.5 Central Water Distribution Device

The Fury nozzle was overly sensitive to the operating pressure and had limited use. A higher velocity, higher volume nozzle with an ability to remotely direct the spray to different areas of the tank could prove more effective.

3.4.6 Remote Water Distribution Devices

The use of three remote water distribution devices worked well for reaching anywhere in the tank. Painting stripes on the different devices would assist identification of them by those viewing on the television monitor.

3.4.7 Use of Coriolis Flowmeter for Waste Transfer

The Coriolis flowmeter used for measuring the waste transferred from SST S-112 to SY farm was shown to be accurate and reliable. The volumes transferred based on the increase in SY tank ENRAF readings often matched within <1% of the volumes calculated from flowmeter data. This type of flowmeter should be considered for use in other similar applications within tank farms.

3.4.8 Breakup of Solids

When large-sized solids are encountered it can take a lot of water to break down the object to a pumpable size. This can become an inefficient use of water and DST space when the volume of large-sized solids becomes great. Increasing the discharge pressure, using recirculation solution, and positioning the nozzle closer to the waste may improve the system's capacity to break up these objects while using less water.

3.4.9 Allowance for Hard Salt Layer in Bottom of Tank

Core sample data for the tank did not indicate the presence of a dense saltcake layer at the bottom of the tank. As retrieval progressed beyond 90% of the starting inventory, the dissolution rate for the salt steadily decreased. The relatively smooth surface of the remaining salt results in much slower dissolution than for the other salt, which was fairly porous. While this material might eventually be retrieved using water, the dissolution rate is so slow as to either be ineffective, or an excessive volume of water will be needed to retrieve the salt. In the future, the potential presence of such a layer needs to be considered during the engineering phase of the process. Methods should be devised to either increase the surface area of the saltcake, increase the temperature of the retrieval fluid to enhance dissolution, or enable the material to be broken up for transfer with recycled supernatant.

3.4.10 Comparison of Best Basis Inventory With Retrieval Results

The assumptions in the BBI calculation process should be reviewed against retrieval results. The BBI is developed using a combination of modeling and sampling data. Incorporating data from retrieval results will allow a better estimate for this waste type in other tanks. This review will provide feedback to personnel responsible for maintaining the BBI and could enable more accurate BBI estimates in the future.

3.4.11 Waste Sampling and Characterization

Future retrieval can benefit from sampling and characterizing the tank waste through all tank layers before retrieval begins. Pre-retrieval analytical data may provide an indication of how easily this waste can be retrieved.

3.5 CONCLUSION

The SST S-112 saltcake waste retrieval technology demonstration improves fourfold or more on the past-practice sluicing baseline in the area of retrieval water use efficiency. The technology was sufficiently flexible as to allow operational changes during the retrieval campaign, including increasing the water temperature and departing from the center-out retrieval method. These results indicate that the saltcake dissolution technology can be an effective solution for retrieving porous saltcake material where water addition is practical. However, it did not meet the majority of the performance objectives including residual waste volume because it was unable to remove the dense saltcake (hard heel). A discussion of the limits of the technology is found in Section 5.0. An alternative technology will be needed to retrieve the remainder of the tank waste.

4.0 LEAK DETECTION, MONITORING, AND MITIGATION

No leaks were detected during the SST S-112 retrieval demonstration. The integrated leak detection and monitoring strategy provided protection to the public, workers, and environment during tank waste retrieval.

RPP-7825 established that leak detection and monitoring consisted of drywell soil monitoring, liquid level monitoring, and material balances. The HFFACO prescribes unique requirements on SST S-112 retrieval demonstration to improve on past practices in the area of leak loss potential and suitability for use in potentially leaking tanks.

The primary goal of the LDMM strategy for the SST S-112 retrieval demonstration is leak mitigation. The approach described in RPP-10413, *Tank S-112 Saltcake Waste Retrieval Demonstration Project Leak Detection, Monitoring and Mitigation Strategy*, using operational controls, retrieval design, and drywell logging, was based on preventing leakage, minimizing leak volumes if a leak should occur, and using available data for indication of possible leakage. The operational history and decades of waste and liquid level monitoring indicate that SST S-112 has not leaked and was sound before starting retrieval.

The following sections describe the LDMM requirements, leak detection monitoring implementation, mitigative approach, chronology, results, and lessons learned. The major results for the LDMM program during SST S-112 demonstration are as follows:

a. Drywell moisture and gamma logging data showed no evidence of leaks during the SST S-112 waste retrieval.

b. Modified static level monitoring demonstrated no evidence to support leakage during retrieval.

4.1 REQUIREMENTS

Requirements for the leak detection and monitoring system are contained in HNF-SD-WM-TSR-006, *Tank Farms Technical Safety Requirements,* specifically TSR Limiting Condition for Operation 3.1.1, "Transfer Leak Detection Systems." Material balances during transfers are required by the TSR Administrative Control 5.11, "Transfer Control," and RPP-12711, *Temporary Waste Transfer Line Management Program Plan.*

The primary procedures governing notification and reporting of leaks are *Occurrence Reporting and Processing of Operations Information* (TFC-OPS-OPER-C-24) and *Environmental Notification* (TFC-ESHQ-ENV_FS-C-01).

Additionally, Milestone M-45-03C from the HFFACO states the following:

> Selected saltcake retrieval technology (or technologies) must seek to improve on past practice sluicing baseline in the areas of expected retrieval efficiency, leak loss potential, and suitability for use in potentially leaking tanks. This demonstration shall also include the installation and implementation of full scale leak detection, monitoring, and mitigation (LDMM) technologies.

An evaluation of improvements related to retrieval efficiency is found in Section 3.2. Improvements related to LDMM are addressed further in Section 4.3.1.

4.2 LEAK DETECTION AND MONITORING

According to plans and requirements set forth in RPP-7825, *Single Shell Tank S-112 Full Scale Saltcake Waste Retrieval Technology Demonstration Functions and Requirements*, the waste retrieval system shall

a. Be designed to detect a cumulative leak loss during the retrieval campaign of 8,000 gal or the system shall be designed using the best available technology that is economically achievable to detect tank leaks during retrieval to as low as reasonably achievable.

b. Have a probability of leak detection of greater than 95%.

c. Have a probability of false alarm less than or equal to 5%.

d. Quantify liquid waste release volumes from SST S-112 if a release is detected during waste retrieval operations.

e. Minimize waste generation to the greatest extent practical, including water introduced into the tanks and solid waste.

f. Be designed and operated to mitigate leak volumes ranging from 8,000 gal to 40,000 gal for the duration of the retrieval demonstration. An operational approach that minimizes the free liquid in the tank shall be employed for waste retrieval, ensuring that the interstitial liquid level remains below its starting level (124 in.).

The SST S-112 retrieval system and retrieval strategy were designed to reduce the possibility of a leak and the potential environmental impact of a leak, should one occur. The leak detection strategy places emphasis on using the best available technology. The U.S. Department of Energy, Office of River Protection has funded the development of new, more sensitive leak detection technologies for the Hanford tanks, but none of the new technologies were mature enough to form the basis for the SST S-112 leak detection strategy. The SST S-112 project evaluated existing in-tank and ex-tank options and determined that tank wall leaks would be most quickly and reliably detected by monitoring the soil around the tank via existing drywells and that leaks from the center of the tank floor would be most reliably detected using static liquid level tests at appropriate times during the retrieval.

The SST S-112 retrieval demonstration strategy for leak monitoring was to use data from the leak detection systems to locate and quantify the leak. Using a combination of technologies allowed a defense-in-depth approach to strengthen leak detection capabilities. Leak detection and monitoring during retrieval demonstration in SST S-112 was accomplished by the use of drywell monitoring, liquid level indicators (ENRAF), leak detectors, radiological monitoring, and material balances (see Table 4-1).

Table 4-1. Leak Detection and Monitoring Methods.

Component	Method
SST S-112	Drywell monitoring (primary), material balance, visual inspection, liquid level indicators
Tank SY-101 and SY-102 (DST receiver for SST S-112)	Annulus leak detectors, radiation monitoring for annulus exhaust air, liquid level indicators
HIHTL	Secondary containment, leak detectors, radiation monitoring

4.2.1 Drywell Monitoring

The primary means of detecting a leak from SST S-112 during retrieval was by monitoring the soil surrounding the tank for gamma radiation and increases in soil moisture content. This is done via the existing drywells in the vicinity of SST S-112. Analyses described by RPP-7825 indicate that this is the most reliable means of detecting a liquid leak from the SST S-112 wall. Success of this approach is contingent on the migration of leaked liquids from the leak site to the vicinity of the drywell. The uncertainty analysis related with drywell monitoring and leak detection can be found in RPP-10413, *Tank S-112 Saltcake Waste Retrieval Demonstration Project Leak Detection, Monitoring, and Mitigation Strategy*, Appendix B.

There are eight drywells near SST S-112 with depths ranging from 100 to 145 ft (Figure 4-1). The drywells are (in clockwise order around the tank starting from due north) 40-09-06, 40-12-02, 40-11-09, 40-11-08, 40-12-04, 40-12-06, 40-12-07, and 40-12-09. Drywell 40-09-06 is associated with SST 241-S-109, and drywells 40-11-08 and 40-11-09 are associated with SST 241-S-111, but these are sufficiently close to be useful for detecting a plume of leaking waste from SST S-112. A chronology of drywell monitoring is included in Table 4-2.

Figure 4-1. Plan View of S-Farm Tanks and Drywells.

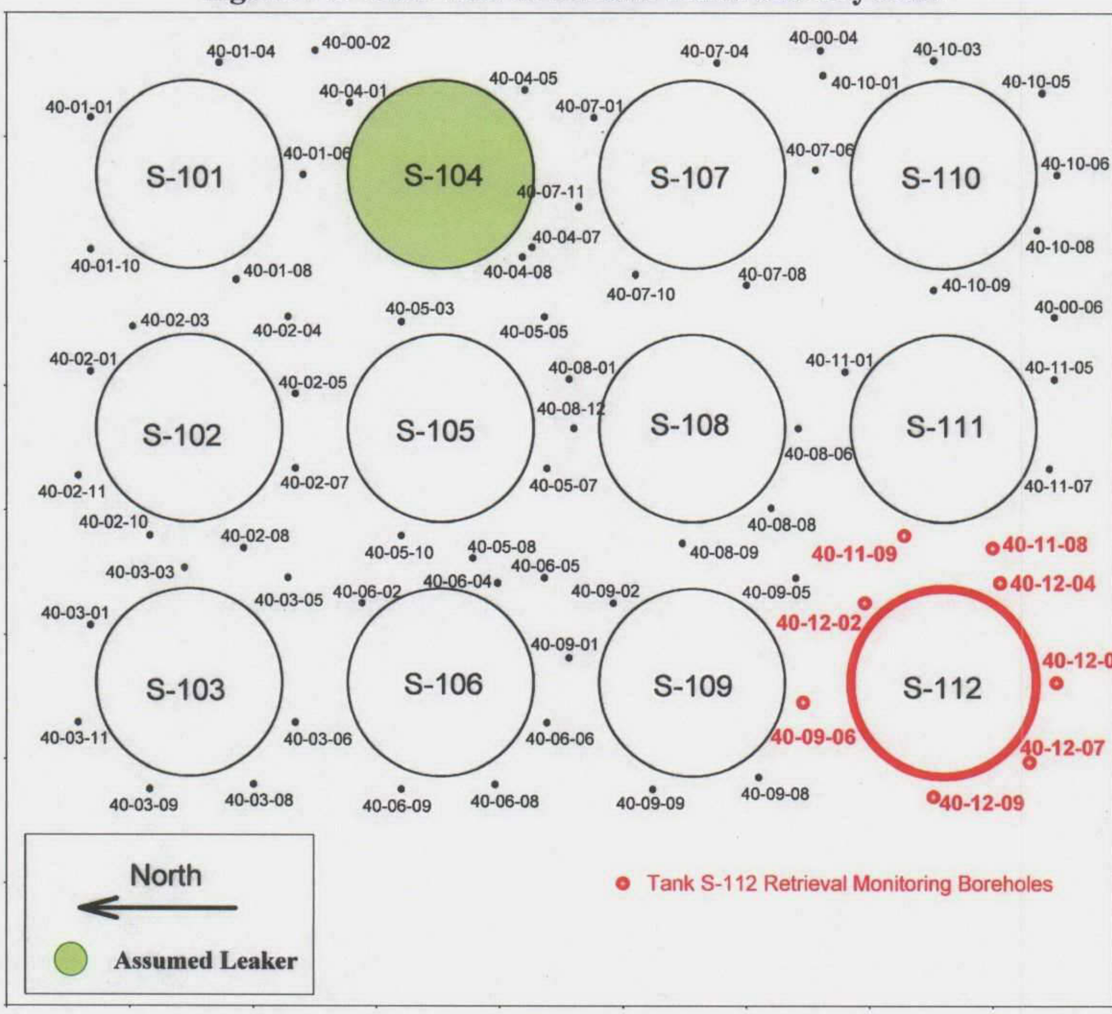


Table 4-2. Drywell Monitoring Chronology.

Date	Item
7/30/1996	Drywell gamma logging baseline established
6/2002	Drywell gamma logging performed
3/2003	Drywell gamma logging performed
8/2003	Drywell gamma logging performed
9/28/2003	Saltcake dissolution demonstration begins, first hand-held neutron moisture logs performed, weekly hand-held moisture logging continues
10/2003	Drywell gamma logging performed during outage for DST receiver tank change (SY-101 to SY-102)
11/2003	Drywell gamma logging performed during training outage
2/2004	Drywell gamma logging performed
5/17/05	Last day of saltcake dissolution retrieval, neutron moisture logs performed for three additional weeks
6/2005 – 8/2005	Drywell gamma logging performed

4.2.1.1 Methodology

The baseline leak detection methodology involved deployment of existing truck-mounted geophysical logging systems using both gamma and moisture monitoring tools. This system was deployed before waste retrieval operations began and at the end of waste retrieval operations. Baseline monitoring uses gamma radiation probes and neutron moisture instruments to detect changes in the radiation and moisture in the soil around the drywell.

A baseline profile was taken prior to retrieval operations, and subsequent monitoring results were compared with that baseline profile. Moisture monitoring using the truck-mounted system was done in each well prior to and after retrieval. During waste retrieval operations, the truck-mounted system was supplemented by the use of manually deployed moisture gauges nominally once a week in each well at depths between 40 ft and 55 ft while actively retrieving the waste. In the event of an unexplained increase in soil moisture content, additional monitoring with the truck-mounted system would have been used to determine if there have been any changes in gamma-emitting radionuclide concentration surrounding the drywells.

The use of manually deployed moisture monitors represents an enhancement to the truck-mounted system by providing more frequent moisture measurements in areas of interest without having to continually deploy the trucks into the farm.

4.2.1.2 Results and Discussion

A baseline profile of the drywells surrounding SST S-112 was taken by the truck-mounted logging systems before retrieval operations started. The baseline monitoring used gamma radiation probes and neutron moisture instruments.

During retrieval operations, hand-held neutron moisture logging was conducted weekly. Subsequent to May 17, 2005 (completion of retrieval), logging was conducted once per week for 3 weeks. The available results from hand-held neutron moisture logging did not show indications of moisture increase in any of the drywells throughout the retrieval demonstration. An example from drywell 40-12-09 is shown in Figure 4-2.

The neutron moisture graph plots depth below surface against instrument counts. The number of counts is related to the moisture content of the soil. The dashed line on the plot shows three standard deviations from the data taken. Using three standard deviations (σ) is a common statistical process control measurement for determining if data is within acceptable limits. Any data consistently approaching or beyond the three σ line requires further investigation. In addition, the areas of concern are generally between 40 and 55 ft below ground surface (Figure 4-3). This is the area of soil that is located near the tank bottom and was compacted during construction of the tank farms. If a leak occurs in the wall of the tank, liquid will likely run down to this point; in addition, the compacted layer can cause liquid from a leak to pool around this area.

The results from truck-mounted gamma logging do not show indications of radiation increase in any of the drywells throughout the retrieval demonstration. An example from drywell 40-12-06 is shown in Figures 4-4 and 4-5. As in the moisture logs, there was no significant increase in the gamma readings throughout retrieval.

There is a possibility that a leak can escape detection by drywell monitoring, especially if the leak originates from near the center of the tank floor. Therefore, modified static level monitoring has been adapted to monitor for leaks from near the center of the tank to minimize this possibility.

4.2.2 Liquid Level Indicators

The overall waste retrieval operating strategy for the SST S-112 demonstration was to reduce the tank liquid inventory and minimize liquid additions during retrieval. Liquid levels were monitored to evaluate liquid inventories and indicate potential leaks in the system to implement this strategy. Daily liquid level measurements were recorded for SST S-112 as well as the DSTs SY-101 and SY-102. The instrument used to measure liquid level is an ENRAF device. The ENRAF device is capable of determining a 0.1-inch liquid level change.

Volumetric methods measure the liquid surface in a static tank and convert the level data to volume data from the known tank parameters. Historically, static level measurements were performed on free-liquid surfaces that covered the waste and were available for level monitoring. In the case of SST S-112, interim stabilization pumping removed the surface liquid. The SST S-112 retrieval strategy included a stilling well that was accessed for level measurement. The stilling well was used for static measurement for several weeks during downtime between retrieval campaigns.

Figure 4-2. SST S-112 Drywell Logs: Neutron Moisture for Well 40-12-09.

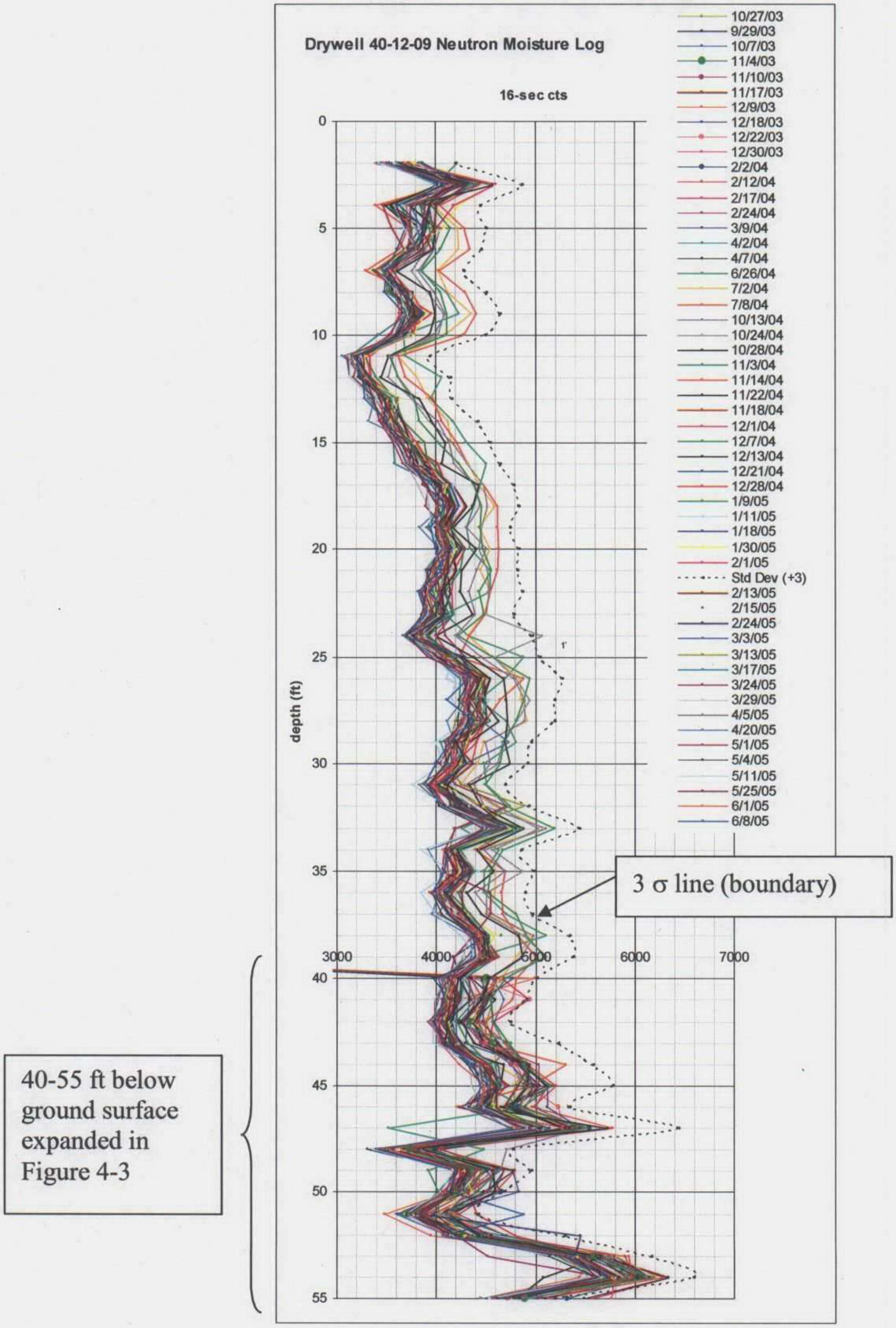


Figure 4-3. Tank and Drywell Diagram with Log for 40-55 Feet Below Ground Surface.

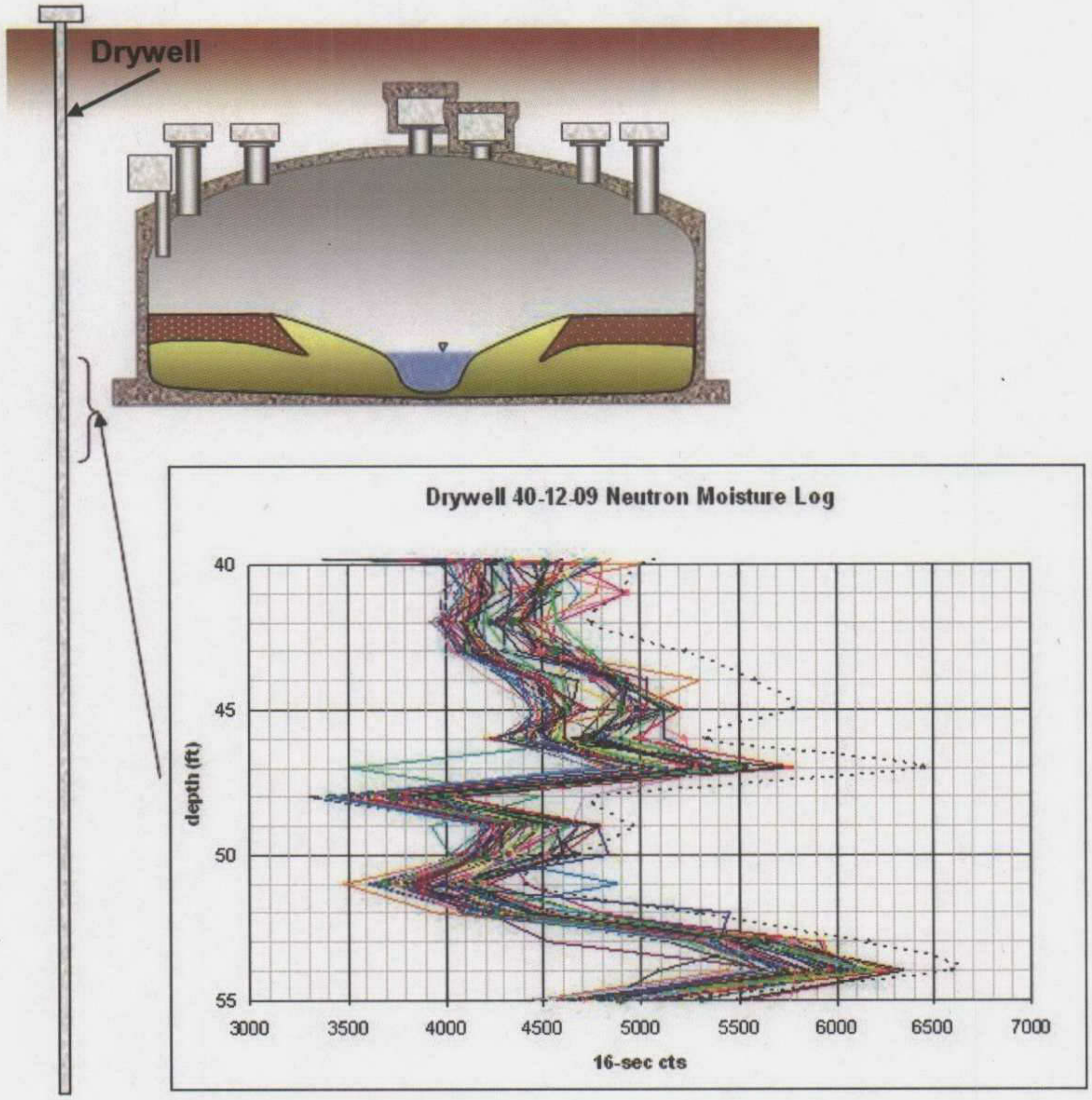


Figure 4-4. Total Gamma for Well 40-12-06.

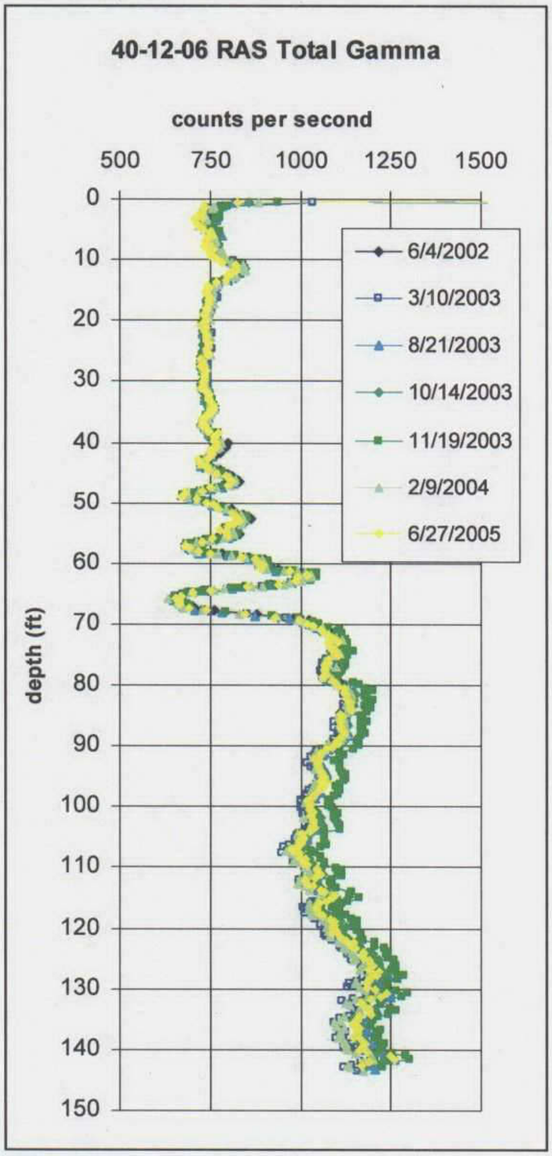
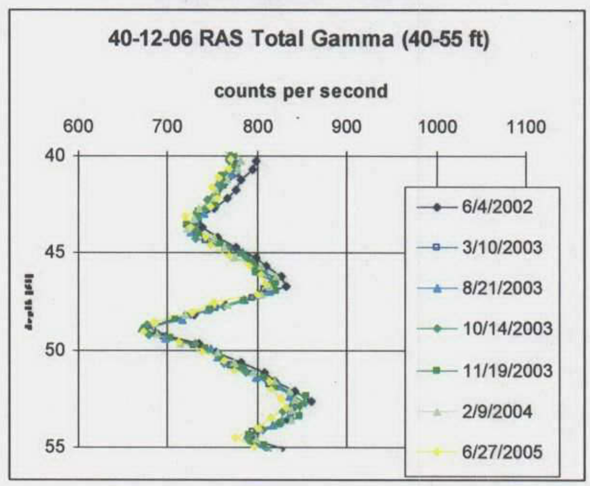


Figure 4-5. Total Gamma for Well 40-12-06 between 40 and 55 Feet.



4.2.2.1 Methodology

Drywell monitoring is not sensitive to leaks from the center of the tank, therefore static level observation was adapted to fill this need. Before level monitoring, the tank liquid level was pumped down as much as practical as part of the normal operational leak mitigation strategy when not sluicing. Following removal of liquid from the central pool, liquid seeps from the surrounding waste into the central pool over a period of time. Consequently, the liquid level slowly rises to an equilibrium level; any lowering of the liquid level could indicate a leak. Any leak will initially be masked by the level rise, but a large leak will become evident. Detection of small leaks is not possible until the liquid level reaches equilibrium, which takes several days or weeks. A small leak (<2 gal/hr) requires level equilibrium to be detectable.

Static-level observations are done near the end of scheduled downtimes associated with transferring waste out of the receiver tank, as well as unscheduled delays. In-tank conditions that impact static level observations include the following:

a. Evaporation from the central pool.

b. Gas accumulation or release from the central pool.

c. Liquids not yet at hydraulic equilibrium with the solids. Weeks may be required for the liquid level to fully equilibrate. However, the liquid level will asymptotically approach the equilibrium level and deviations from this anticipated trend can be used as a potential indication of a leak. An indication of a leak would be a drop in the liquid level during this period of time, with the ventilation secured.

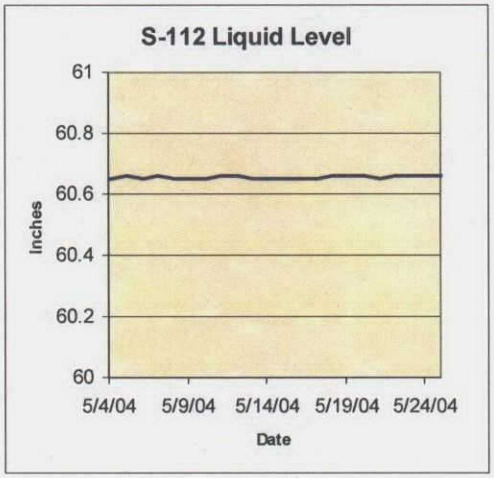
d. Undissolved waste sloughing/falling into the pool.

To minimize the uncertainty of static level observations, the observation periods were performed when the influences of the disruptions are reduced (e.g., not at the start of retrieval).

4.2.2.2 Results and Discussion

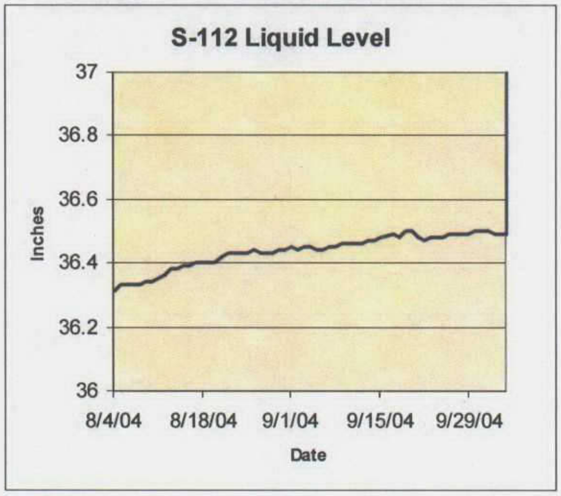
Liquid level was monitored during downtime when no pumping was being performed and no liquid was being added to the tank. As described above, the liquid level would typically slowly rise until the equilibrium level was reached. Between May 4 and 25, 2004, the liquid level reading typically varied by ±0.02 in. indicating having reached equilibrium (Figure 4-6).

Figure 4-6. SST S-112 Liquid Level Between May 4 and 25, 2005.



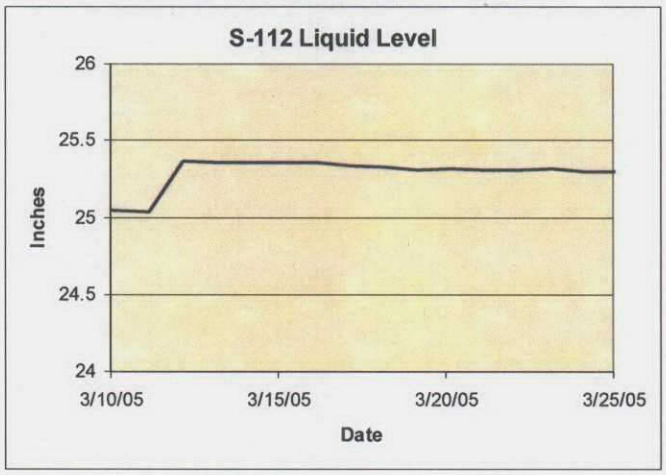
An example of how the liquid level would slowly rise to an equilibrium level is shown by the period between August 4 and October 1, 2004 (Figure 4-7). The changes after August 22 are small enough to indicate that the liquid level had reached equilibrium. This stable liquid level confirms no leaks occurred at this level.

Figure 4-7. SST S-112 Level Between August 4 and October 1, 2005.



Readings during March 2005 indicate a change of level less than 0.1 in. over the span of a week (Figure 4-8). The slight downward trend shown in Figure 4-8 is within the tolerance of a stable liquid surface.

Figure 4-8. SST S-112 Liquid Level Between March 10 and 25, 2005.



All of these readings and predictable responses by the liquid level during nonoperating periods confirm that no leak occurred. This evidence, paired with the drywell data, provides confidence that there was no leakage from the tank during waste retrieval.

4.2.3 Leak Detectors

Liquid waste and slurries were transferred from SST S-112 to DSTs SY-101 and SY-102 using temporary HIHTLs and existing valve pits. Leakage from the primary over-ground transfer hose (inner hose) is contained by the secondary confinement system (outer hose). The secondary confinement system is designed to drain any fluid released from the primary hose to a common point for collection, detection, and removal. Any leakage into the secondary containment drains towards either the 241-S-A valve pit or the 241-S-12A pump pit. Leak detection elements installed in the valve and pump pits actuate an alarm and annunciator light in the control trailer if a leak is detected, and the transfer pump is automatically stopped.

DSTs SY-101 and SY-102 were monitored for leaks in their inner shells by a conductivity probe leak detection system installed in the tank annulus. Slots in the concrete (that supports the tank at the bottom) are designed to drain any leakage to the annulus floor. Conductivity probe assemblies on the annulus floor would activate an audible alarm and an annunciator panel light in the event of liquid leaking to the annulus so that mitigation could begin according to procedure.

If a potential leak is detected in the transfer lines, transfer operations are stopped and the evidence investigated. Transfer operations resume after resolution of the evidence.

Throughout the retrieval campaign, no transfer line or DST primary liner leaks were detected by any of the leak detectors in the pump pits or the DST.

4.2.4 Radiation Monitoring

A continuous air monitor was operated to detect airborne radionuclides entrained in the ventilation exhaust stream of the annulus of DSTs SY-101 and SY-102. Detection of radiation exceeding a set limit in the annulus of the DST activates an audible alarm and an annunciator panel light, initiating mitigative action.

In addition, HIHTL walkdowns were performed once every 12 hours during retrieval with a radiation monitor to check for leaks from the transfer line.

The continuous air monitor for the DST annulus detected no radiation levels above background during retrieval that could have been attributed to leak-induced airborne radionuclides. The HIHTL walkdowns also detected no radiation levels above background during retrieval.

4.2.5 Material Balance

Process control measurements were used periodically to perform a material balance and determine the change in SST S-112 waste inventory. Once determined, the change in waste inventory was compared to the anticipated change (gallons of brine produced and/or released per gallon of water added, adjusted for changes in the central pool and interstitial liquid volumes). Engineering evaluation of the material balance calculations were performed to identify transfer/receipt discrepancies for indications of a leak (RPP-15085).

Based on the data generated by the retrieval operations material balance, the amount of waste transferred may have been overestimated. During the retrieval demonstration, the material balance indicated the recovery of over 614,000 gal of waste. The starting volume of waste was estimated to be about 614,000 gal and an estimated 31,000 gal of waste remain in the tank following retrieval. Salt dissolution is the primary means of waste retrieval and the SpG and volume of the transferred material is required to determine the transferred mass. A correlation of SpG to waste volume is used to estimate the amount of waste transferred. This correlation is based on a best fit regression line to a collection of lab data obtained using SST 241-S-102 sample data and may have been overestimated for S-112. It is also possible that the estimate of the starting volume of the waste was inaccurate due to measurement difficulties.

Material balances that were used to account for the water added, the brine volume and SpG, and the volume change in the DST receiver indicated no significant discrepancies during the transfers. That is, the volume of liquid transferred matched the volume change in the DST receiver.

4.3 MITIGATION

4.3.1 Leak Mitigation

Leak mitigation is defined as technologies, waste retrieval methods, or systems that can reduce the potential for a leak to occur, the volume of a leak if it were to occur, and actions taken to minimize leak volumes in the event a leak is detected during waste retrieval. The retrieval system and operational strategy are designed to minimize the leak potential (both the likelihood and volume of a leak). The key elements of SST S-112 leak mitigation planned in RPP-10413 were the following:

a. Control in-tank liquid inventory during retrieval to less than previous nonleaking interstitial liquid level. Years of static level monitoring show the tank to have not leaked below this level.

b. Retrieve waste from the center of the tank out to minimize liquid contact with the tank wall. In the center-out retrieval strategy, dissolved waste and released interstitial liquids drain quickly into a central pool and can be rapidly pumped from the tank if a leak is detected.

c. Design the retrieval system and operational strategy to minimize "time at risk." By minimizing the time at risk, potential leak volumes are limited in size. The retrieval was originally estimated to take two to four weeks to complete.

d. Use the retrieval pump to minimize SST S-112 liquid inventory between retrieval campaigns (e.g., while waiting for cross-site transfers) to further reduce any leak-driving head and migration of liquids to the tank wall.

e. Minimize potential leak volume by providing a pump, located as close to tank bottom as possible, which is capable of rapidly removing liquids from SST S-112 if a leak were to be detected.

In the event a tank leak was indicated, specific actions would be taken to facilitate mitigation. Addition of sluicing water would be stopped and as much liquid as possible would be removed from the tank. The State of Washington Department of Ecology (Ecology) would be notified. Drywell logging would be conducted to survey for plumes. An investigation of the evidence for a leak would be conducted. If the investigation did not support the conclusion that the tank has leaked, retrieval operations would be resumed. If the investigation indicated a leak had occurred, the new conditions would be assessed to determine the appropriate path forward. Retrieval operations would continue only if and when it was established that it was prudent to do so.

4.3.2 Mitigation Results

The key elements in the SST S-112 mitigation plan that were successfully implemented during the saltcake dissolution demonstration include the following.

a. In-tank liquid inventory was controlled to less than the previous nonleaking interstitial liquid level during retrieval.

b. Waste was retrieved from the center of the tank out to the extent possible to minimize liquid contact with the tank wall.

c. The retrieval pump was used to minimize SST S-112 liquid inventory between retrieval campaigns.

d. Potential leak volume was minimized by providing a pump, located as close to tank bottom as possible, which is capable of rapidly removing liquids from SST S-112.

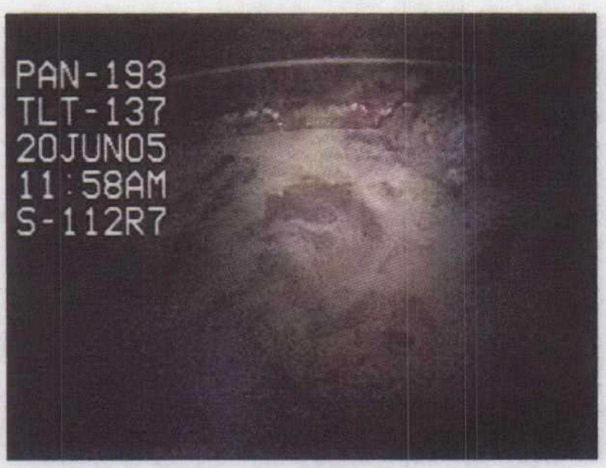
One key element was not achieved during the saltcake dissolution demonstration. The initial retrieval duration was predicted to be 2 to 4 weeks. The predicted time frame was based on the pumping rate and not the salt dissolution, which led to the "time at risk" becoming more than 598 calendar days. All of the other key elements were achieved.

Water use was stopped short of the predicted final use (1,321,400 gal); about 1,225,600 gal of the water were used during the saltcake dissolution demonstration. Each water addition was monitored and controlled. Typically, the liquid inventory in SST S-112 was minimized and the liquid level was reduced to a minimum of hard heel waste during transfers. The exception was during later stages of the retrieval demonstration when water was added to soak the waste to improve retrieval efficiency.

The final volume of residual waste in SST S-112 is estimated to be about 31,000 gal, as determined through ENRAF measurement. See Figures 4-9 and 4-10. There was a fairly even layer of saltcake across the tank and a small liquid pool around the location of the pump, indicating that the final volume of waste and water had been minimized. Consequently, the potential for leaks as well as the volume of a potential leak were minimized.

Figure 4-9 Final Saltcake Level in SST S-112.

Figure 4-10 Final Liquid Pool by Pump.



In addition to the SST S-112 mitigation strategy, the HFFACO's additional requirements include the following:

a. Seeking improvement in leak loss potential.

b. Seeking improvement in suitability for use in potentially leaking tanks.

c. Installation and implementation of full-scale LDMM technologies.

In regard to leak loss potential, the demonstration technology made improvements through water minimization, controlled water additions, and controlled soak times. Recirculation was used to increase waste contact with water and reach target brine densities and maximize the amount of waste transferred with a given volume of water.

This technology can be used in certain potentially leaking tanks. In the case of a tank with a leak in the upper area of the tank wall, this technology has shown to have the capacity to maintain a baseline liquid level, preventing a leak from upper areas of the tank. In the case of potentially leaking tanks with potential leaks in the lower area of the tank, the saltcake dissolution technology would not improve on past-practice sluicing.

Drywell monitoring was performed to demonstrate a full-scale LDMM technology that could potentially detect changes in soil moisture around the SST S-112, accomplishing a requirement from the HFFACO. Results from drywell monitoring are found in Section 4.2.1.2.

4.4 CONCLUSION

Based on the available data presented in Sections 4.2 and 4.3, there is no evidence of a tank leak occurring during the SST S-112 retrieval demonstration. The SST S-112 LDMM program focused on a mitigation strategy to successfully control potential leaks. This strategy included the following:

a. Control in-tank liquid inventory.

b. Center-out retrieval method.

c. Controlled and monitored additions of water.

d. Use of a pump located close to the tank bottom.

e. Liquid inventory minimization between retrieval campaigns.

The strategy of the LDMM program was successfully implemented. The S-112 demonstration met the HFFACO requirements to seek improvement in leak loss potential, suitability for use in potentially leaking tanks, and installation and implementation of a full-scale LDMM technology.

Functions and requirements were also established for the SST S-112 retrieval demonstration. Table 4-3 shows the requirements listed in RPP-7825 and if those requirements were met. Considerations for improvements for the SST S-112 retrieval system are addressed in Section 4.5.

4.5 LESSONS LEARNED

Future tank retrievals can benefit from the results of the SST S-112 LDMM process. This was the first successful demonstration of saltcake dissolution system at the tank farms. Additional enhancements can improve the effectiveness of the LDMM program and are being reviewed. These improvements include the following.

a. Use salt dissolution as well as pumping rate information as a basis for retrieval duration and factor this duration into the LDMM strategy.

b. Achieve better distribution on the recirculation lines to contact more waste and minimize the volume of fresh water added to the tank.

c. Review the assumptions in the BBI calculation process against retrieval results. Review will provide feedback to personnel responsible for maintaining the BBI and could enable more accurate BBI estimates in the future.

d. The application of saltcake dissolution to a potentially leaking SST would need to evaluate the waste dissolution rate.

These improvements should provide for safer operations, a more accurate basis for LDMM calculations, and a more effective LDMM program.

Table 4-3. SST S-112 Functions and Requirements Results.

Requirement	Approach, Action, or Response
Be designed to detect a cumulative leak loss during the retrieval campaign of 8,000 gal or the system shall be designed using the best available technology that is economically achievable to detect tank leaks during retrieval to as low as reasonably achievable.	The SST S-112 Project deployed the system that represents the best available technology gamma and neutron moisture detection surveys in the drywells near SST S-112. This approach is augmented with in-tank methods to provide defense-in-depth leak detection and monitoring.
Have a probability of leak detection of greater than 95%.	RPP-10413 provides the uncertainties associated with leak detection capability and ex-tank drywell monitoring techniques are evaluated. 95^{th} percentile leak volumes are presented for both methods.
Have a probability of false alarm less than or equal to 5%.	RPP-10413 provides an explanation to define a minimum detectable leak volume tied to a probability of false alarm. The project used an investigative approach to leak detection that is described in the process control plan (RPP-15085).
Quantify liquid waste release volumes from SST S-112, if a release is detected during waste retrieval operations.	No release was detected during waste retrieval operations. The retrieval system was capable of detecting and quantifying leaks as defined in RPP-10413.
Minimize waste generation to the greatest extent practical, including water introduced into the tanks and solid waste.	Although target waste retrieval efficiencies were not met, waste generation was minimized by recirculating the waste and allowing longer periods of soak time to increase the SpG. Final water use was below predicted use.
Be designed and operated to mitigate leak volumes ranging from 8,000 gal to 40,000 gal for the duration of the retrieval demonstration. An operational approach that minimizes the free liquid in the tank shall be employed for waste retrieval, ensuring that the interstitial liquid level remains below its starting level (124 in.).	Leak mitigation was implemented including an operational approach to minimize free liquid through center-out retrieval. The liquid level baseline of 124 in. was exceeded early in retrieval due to an inability to transfer waste. After the first initial batches of waste were sent to DST SY-101, a potential retained gas issue developed and the receiver tank was switched to DST SY-102. During the outage to switch between tanks, interstitial liquid retained in the upper areas of the saltcake began to drain downward, increasing the liquid level at the stilling well. A letter was sent to Ecology notifying them that the baseline had been exceeded. Ecology approved the actions that were being taken and the water was immediately pumped out when the transfer line to DST SY-102 was functional. The baseline was not exceeded after this event.

5.0 LIMITS OF TECHNOLOGY

The HFFACO Milestone M-45-03C states in part that DOE shall

> Complete full scale saltcake waste retrieval technology demonstration at single-shell SST S-112. Waste shall be retrieved to the DST system to the limits of the technology (or technologies) selected....

The intent of this requirement is that the SST S-112 demonstration retrieval campaign continue until the waste retrieval system recovers as much waste as technically possible.

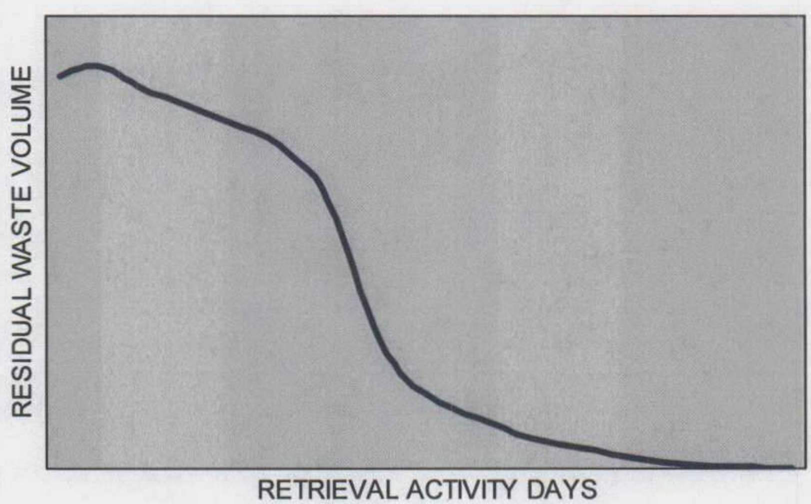
This section presents information showing that the requirement of removing as much waste as technically possible from SST S-112 via the current saltcake retrieval system was met, and that the limits of technology have been reached. Performance of the saltcake retrieval system decreased over time to the point where only negligible waste was being retrieved with each additional batch. Since the saltcake retrieval system reached its technological limit, demonstration saltcake dissolution retrieval operations for SST S-112 were terminated.

Unless otherwise noted, data in this section were developed in accordance with TFC-ENG-CHEM-P-47, *Single-Shell Tank Retrieval Completion Evaluation.*

5.1 IDENTIFYING THE LIMIT OF TECHNOLOGY

M-45-03C does not prescribe a method or criteria for deciding when a technology has reached the limit of its capability to retrieve waste. Figure 5-1 illustrates the general concept of diminishing returns over time as retrieval progresses and the retrieval technology reaches its limit.[1]

Figure 5-1. Limits of Technology Model.



During the earliest portion of the hypothetical campaign, the results of initial retrieval events and the nature of the waste encountered may require adjustments to the system to maximize the

[1] Figure 5-1 does not represent actual retrieval results. Actual results for SST S-112 are shown graphically in Figure 5-3.

efficiency of the technology. During the middle period, the operational parameters have been optimized and efficient operation of the technology removes relatively large volumes of waste. In later stages, the small volume of waste remaining and the reduced operational efficiencies cause retrieval time to increase in relation to volume of waste recovered. In the final days, the decline in quantity of waste recovered per unit time approaches zero, indicating that retrieval efficiency has diminished to the point where the limit of the technology has been reached.

In making the determination that the limits of the saltcake retrieval technology had been reached, DOE and CH2M HILL relied primarily on a decrease over time in the specific gravity (SpG) of slurry volumes transferred from SST S-112, which indicated a continuing reduction in gallons of waste transferred from SST S-112 per gallon of water used. This observed decline in the system's capacity to retrieve waste pointed to other specific indicators that the technology was becoming ineffective:

a. The low volume of waste retrieved per day in the latter stages showed that the saltcake dissolution process had essentially stopped.

b. Visual observation established that waste that could be readily dissolved by the water and retrieved by the pump had been removed from the tank.

c. Visual observation also established that sluicing was not effective in breaking up the surface of the hard waste in the heel.

Confirmation was provided by mass balance and DST space usage calculations that showed a substantial loss of efficiency during the campaign, as discussed in Sections 5.1.3 and 5.2.3

5.1.1 Specific Gravity of the Brine

The SST S-112 retrieval process involved applying water to dissolve saltcake. The resultant solution, essentially a brine containing some suspended solids, flowed toward the pump and was removed from the tank. The brine was transported through a pipeline to a DST. This process was repeated over a period of 70 operating days.

The primary data tool for identifying the limits of the demonstration technology at SST S-112 was the SpG of the brine. The SpG readings were available on a real-time basis.

The SpG of saltcake is in the range of 2-2.5. The SpG of water is 1.0. The target SpG for the saltcake brines during the demonstration was 1.35. The closer the brine density got to 1.0 the less salt was being retrieved per volume of water used.

Over time, the SpG of brines declined toward 1.0. The decline toward 1.0 indicated that very little waste was being retrieved.

5.1.2 Visual Observation

Visual observation of the tank was conducted using an in-tank camera. During the later stages of retrieval, when essentially all porous and crumbly saltcake had been dissolved, the hard waste in the tank heel became visible. The saltcake retrieval technology was visually observed to be unable to break the surface of the hard waste.

5.1.3 Mass Balance

The volume of water added to SST S-112 and the volume and density of the brines pumped from the tank were measured and recorded. The difference between the mass pumped to the DSTs and the mass added to SST S-112 provided estimates of waste removed for each operation. Dividing the mass of waste removed by the total mass transferred resulted in an estimate of efficiency. A decline in efficiency over the course of a campaign is another indicator that a technology's limit was being reached.

5.2 DETERMINATION THAT THE LIMIT OF TECHNOLOGY HAS BEEN REACHED

Retrieval operations were suspended on May 17, 2005. Subsequent review of data and visual observation of the tank indicated that the efficiency of waste retrieval from S-112 was approaching zero. The CH2M HILL responsible engineer established that the limit of the saltcake retrieval system's capacity to retrieve waste from tank S-112 had been reached. This determination was based on (1) SpG readings, (2) direct observation of remaining waste and of the effect of the retrieval technology on the remaining waste, and (3) retrieval efficiency.

CH2M HILL engineering personnel noted that 2 million gal of DST space had been allocated for retrieval of S-112, and that 1.6 million gal of space had been used through May 18. Engineering personnel calculated that, with continuing loss of efficiency and an expected average remaining efficiency of less than 3% for the remainder of retrieval if use of the saltcake dissolution technology continued, approximately 1 million gal of additional DST space would be required to retrieve S-112 to a residual waste volume no greater than 360 ft^3. This course of action would have required 600,000 gal of DST space in excess of the space that had been allocated.

When the decision was made that the limit of technology had been reached, retrieval operations were terminated. The following sections describe the trends in SpG and the results of visual observation that formed the basis for determining that the limit of the saltcake retrieval technology's capacity had been reached. Material balance data was used to confirm that the limits of technology had been reached.

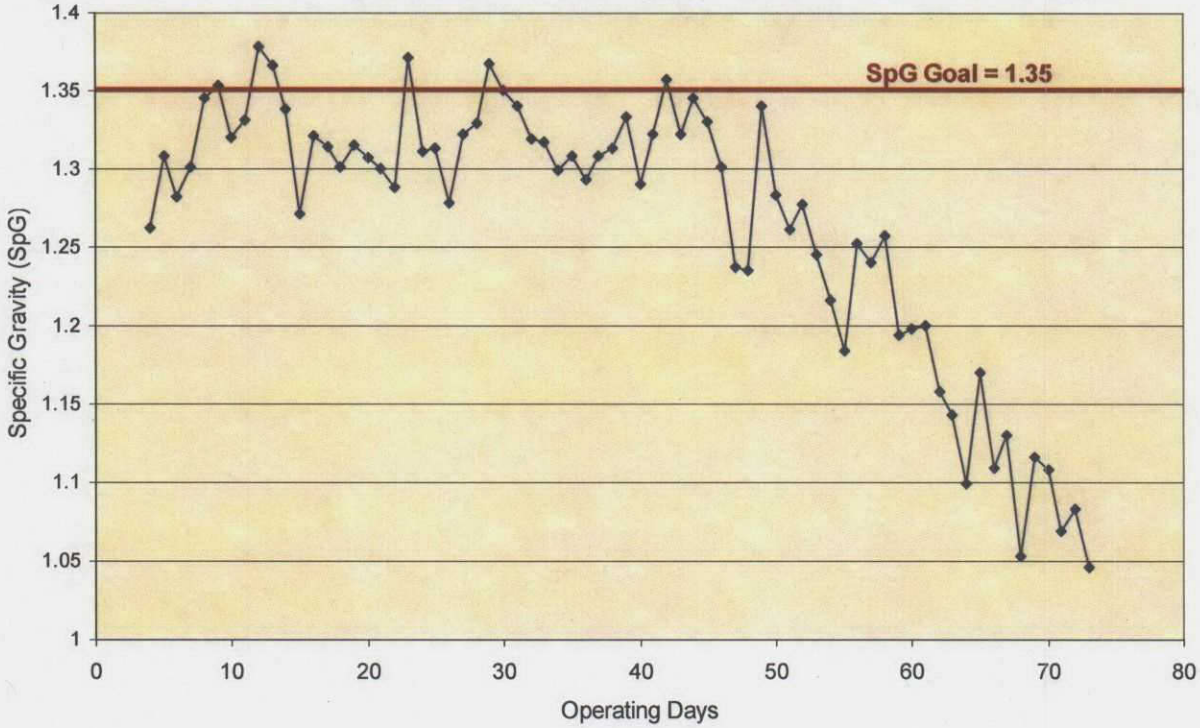
5.2.1 Trend in Specific Gravity of the Brine

Figure 5-2 shows the SpG of the brines transferred from S-112 on a daily basis. On many days, more than one batch was transferred to the DSTs. While the SpG of individual transfers varied, a clear trend of declining SpG was indicated over the course of the campaign. In the later stages of the campaign, the brine contained only dilute solutions of waste, indicating that the content of the slurry was approximating water and the limit of the system to retrieve waste was being reached. Table 3-1 contains data underlying Figure 5-2.

5.2.2 Result of Visual Observations

In the latter stages of the demonstration campaign, visual observation revealed that the retrieval technology had been effective in removing the saltcake but that it could not break the surface of the hard waste in the heel. The failure to break the surface indicated that the saltcake retrieval technology had little or no capability to retrieve the remainder of SST S-112 waste.

Figure 5-2. Average Specific Gravity of Brines Transferred per Operating Day.



5.2.3 Trend in Retrieval Efficiency

Figure 5-3 represents waste retrieved per day as calculated by mass balance. Figure 5-4 graphs retrieval efficiency per batch based on mass balances. The trend reported in both figures corresponds to that of a technology meeting its limits as indicated by a significant reduction in waste being removed for effort expended. Figure 3-2 illustrates the effect of declining SST S-112 waste-per-gallon-of-water retrieval efficiency on planned DST space use.

5.3 CONCLUSIONS

The limit of technology requirement established in HFFACO Milestone M-45-03C was met for the SST S-112 saltcake waste retrieval technology demonstration. Data from instrumentation, direct observations and data trend analysis confirmed that waste retrieval was continued until the saltcake retrieval system had reached the limit of its capacity to retrieve waste from SST S-112.

The SST S-112 saltcake retrieval demonstration was conducted to determine the effectiveness of a modified sluicing technology on the saltcake portion of the waste in the tank. Modified sluicing proved effective in dissolving the saltcake in SST S-112 and in removing the dissolved waste from the tank.

Figure 5-3. Waste Transferred per Operating Day.

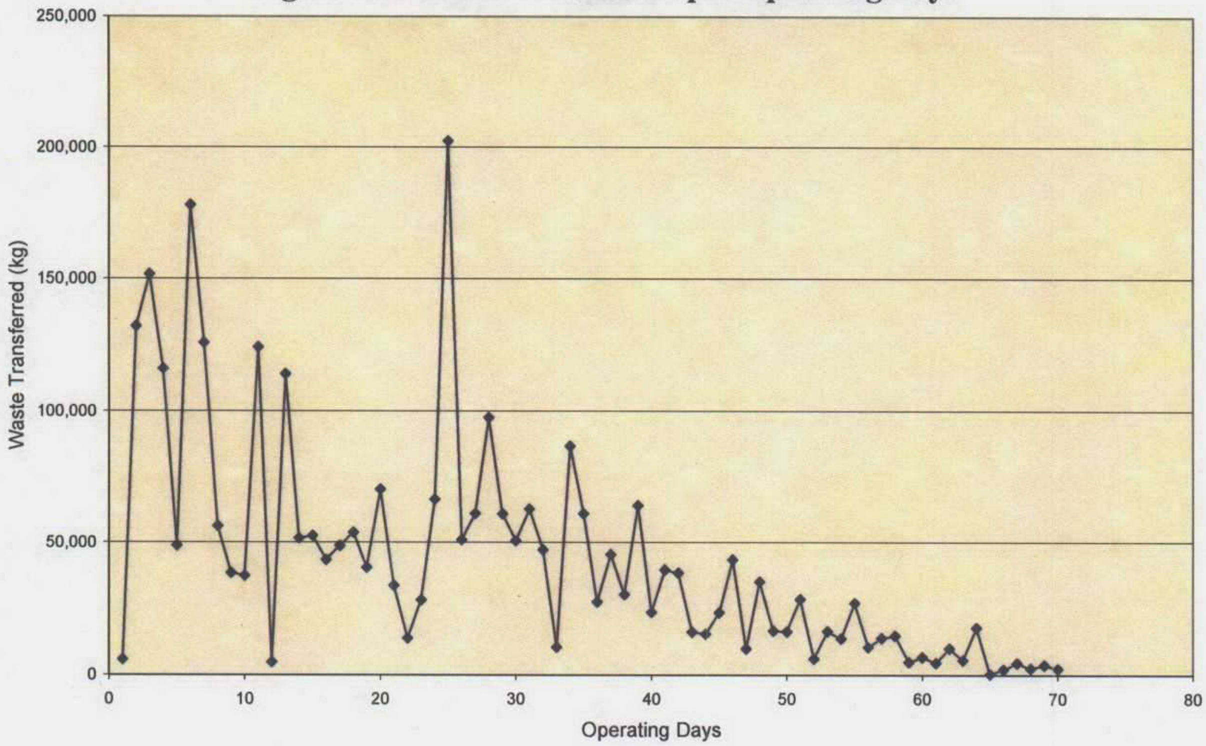
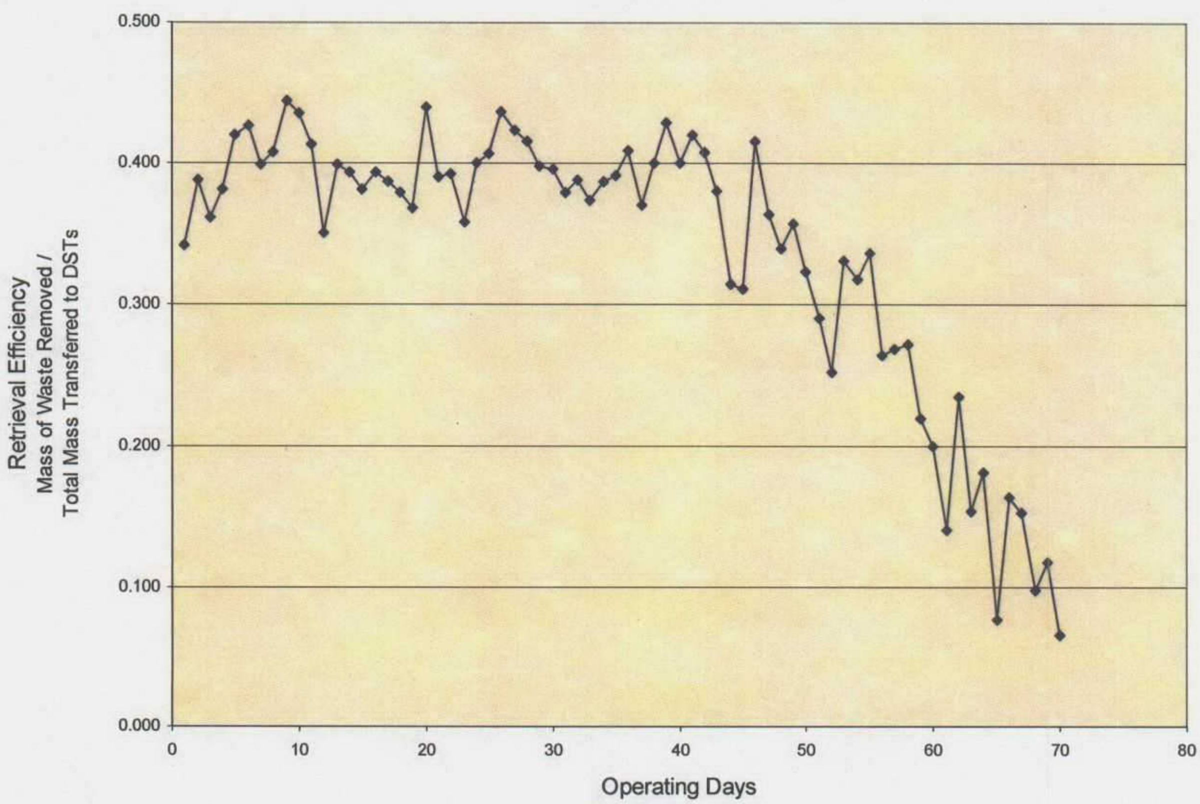


Figure 5-4. Retrieval Efficiency per Operating Day.



6.0 TANK VOLUME MEASUREMENT

This section presents information describing the estimated volume of waste remaining in SST S-112 after completion of the saltcake waste retrieval demonstration required for the tank. Operations proceeded at SST S-112 until the limit of the saltcake waste retrieval system's capacity to remove waste was reached. Subsequently, a field measurement of the residual waste was performed. The measurement established that the volume of the waste remaining in SST S-112 was 31,000 gal or 4,144 ft^3.

Retrieval is planned to resume using another technology. When S-112 retrieval activities are complete, the volume of the residual waste will be measured using the video camera/Computer Aided Design modeling system as required by RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives.*

6.1 WASTE VOLUME MEASUREMENT PROCESS

Table 6-1 describes the specific calculations and observations used to determine the remaining volume, as well as the timing of the determination. Figure 6-1 shows a portion of the tank knuckle joining the wall and bottom of SST S-112 after retrieval.

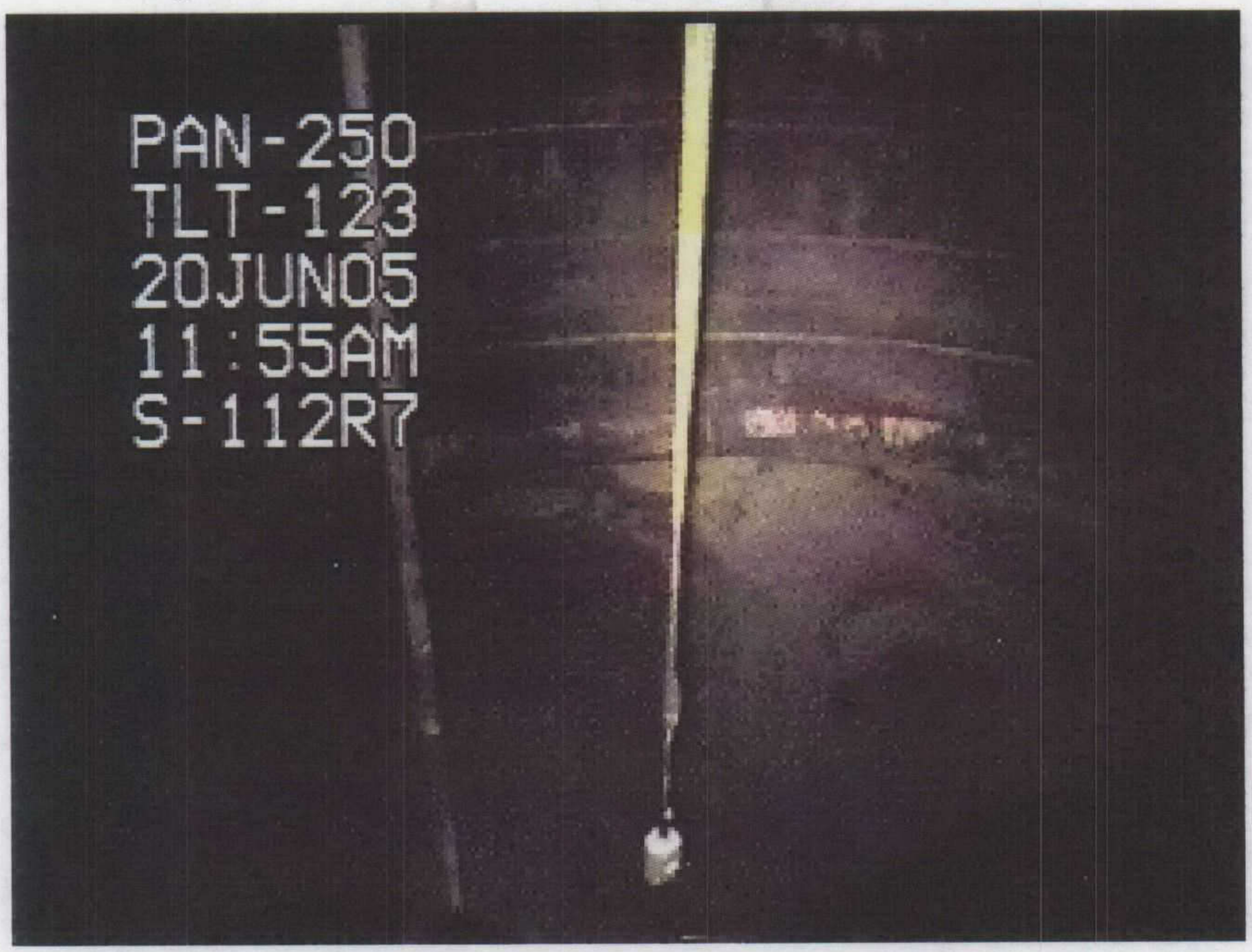
As noted, retrieval of S-112 is not complete, and M-45-00 criteria for retrieval have not been satisfied. Therefore, waste remaining on tank walls, on stiffener rings, or on in-tank equipment has not been estimated. Estimates of waste remaining on these portions of the tank will be incorporated into the calculation of total waste remaining at the conclusion of retrieval.

Table 6-1. SST S-112 Residual Waste Volume Determination.[a]

Process Step	Calculation Methods and Volumes
Final waste transfer	7:00-9:00 p.m. on 5/17/2005.
Surface level of waste prior to transfer	22.18 in.
Volume of material below surface prior to transfer	22.18 in. = 38,022 gal, using the RPP-13019, *Determination of Hanford Waste Tank Volumes,* tank volume calculator.
Status of waste surface prior to transfer	CH2M HILL engineering personnel estimated that 90% of the surface was covered by liquid and that less than 500 gal of waste solids projected above the liquid surface.
Retrieval preparation	1014 gal of water were added to SST S-112.
Waste/water volume transferred	8436 gal of solution were transferred from SST S-112 to DST SY-102.
Volume of remainder (gal)	38,022 gal + 500 gal observed above the liquid surface + 1,014 gal added water – 8,436 gal retrieved = 31,100 gal
Rounded remainder volume (gal)	31,100 gal rounded = 31,000 gal of waste remaining in the bottom of S-112.
Rounded remainder volume (ft^3)	31,000 gal/7.481 gal/ft^3 = 4,144 ft^3 of waste remaining in the bottom of S-112.

[a] As recorded in Tank Monitor and Control System 5/17/2005 13:06

Figure 6-1. View of SST S-112 Knuckle Joining Sidewall and Bottom.



6.2 CONCLUSIONS

The calculated volume of residual waste in SST S-112 was 4,144 ft^3 at the time the saltcake demonstration retrieval was completed, which is equivalent to 5% of the waste by volume in SST S-112 at the start of the retrieval campaign. This result does not meet the M-45-00 retrieval criterion of 360 ft^3 and does not meet the M-45-03C goal of retrieving 99% of the tank contents by volume in accordance with the DOE best-basis inventory data of 8/1/2000. Additional retrieval of SST S-112 is planned to meet the M-45-00 and new milestone M-45-13 criteria.

7.0 RESIDUAL WASTE INVENTORY AND RISK ASSESSMENT

This report documents the retrieval condition for the full-scale saltcake waste retrieval technology demonstration at SST S-112. Because no sample was taken after the demonstration, a post-retrieval risk assessment is conducted using existing data only. Further retrieval of SST S-112 using an additional available technology is planned to achieve Milestone M-45-00 retrieval criteria. On completion of additional SST S-112 retrieval, sampling of the residual waste will be conducted. Characterization of the final waste will be performed, and the risk assessment will be updated.

Results of the risk assessment for the residual waste in SST S-112 using BBI data show that the estimated Incremental Lifetime Cancer Risk, Hazard Index, and all pathways farmer (APF) and target organ doses do not meet performance objectives prescribed for closure of the Waste Management Area (WMA) S-SX that includes SST S-112. Additional retrieval will be required to meet the HFFACO residual limit of 360 ft^3.

This section describes the derivation of residual tank waste inventory in SST S-112 consistent with the BBI methodology defined in RPP-7625, *Best-Basis Inventory Process Requirements,* and presents the volume estimates for saltcake and sludge in the residual waste of 31,000 gal (4,144 ft^3). Based on requirements established in RPP-7825, *Single Shell Tank S-112 Full Scale Saltcake Waste Retrieval Technology Demonstration Functions and Requirements*, the activity of radionuclides and mass of nonradionuclides (chemicals) remaining in SST S-112 were estimated. These estimates were used to calculate the long-term human health risk consistent with the methodology documented in RPP-21596, *Risk Assessment for Waste Management Area S-SX Closure Plan.*

7.1 BEST-BASIS INVENTORY

The concept of the BBI was introduced in September 1995 in the document WHC-SD-WM-WP-311, *Work Plan for Defining a Standard Inventory Estimate for Wastes Stored in Hanford Site Underground Tanks.* The purpose of the BBI was to provide an official database for tank waste inventory estimates at the Hanford Site. The BBI process involves developing and maintaining waste tank inventories that consist of 25 chemical and 46 radionuclide components for 177 underground storage tanks. These tank inventories provide waste composition data for safety analyses, risk assessments, and waste retrieval, treatment, and disposal operations (RPP-7625). To develop the BBI, all existing sources of data were screened to assess the acceptability of the data. When conflicting values occurred, a methodology for distinguishing between conflicting data was established and documented.

Subsequent to this development, total tank inventory estimates were made and standard best-basis chemical and radionuclide inventories were derived for each of the SSTs and DSTs (HNF-SD-WM-TI-740, *Standard Inventories of Chemicals and Radionuclides in Hanford Site Tank Wastes*), by comparing the tank inventory estimates with global inventory estimates based on fuel process records from Hanford Site process plants. Sample data were used as an inventory source when available, but for many tanks specific values were derived from the Hanford Defined Waste (HDW) Model (LA-UR-96-3860, *Hanford Tank Chemical and Radionuclide Inventories: HDW Model*).

The BBI also provides inventory estimates by waste phase. Waste phases include supernatant, saltcake solids, saltcake liquid, sludge solids, sludge liquid, and retained gas. In tanks where interstitial liquid has not been measured separately due to little or no drainage from sludge samples or where saltcake and liquids form a slurry and are analyzed together, the solids and liquid portions of the sludge and/or saltcake are combined and defined as "sludge" or "saltcake."

Maintenance of the BBI is an ongoing effort. Because waste is being transferred into or out of certain tanks, inventories of those tanks are updated on a quarterly basis. Included also in the update are new sample data and advances in process knowledge or application of available data.

7.2 PRE-RETRIEVAL TANK WASTE PROFILE

SST S-112 received REDOX first-cycle waste from 1952 through 1955. The predominately liquid volume remained in the tank until the end of 1973. In 1974, SST S-112 received 242-S Evaporator residuals and recycled supernatants and by the end of 1975 contained primarily saltcake. The tank was removed from service in the second quarter of 1976, labeled inactive during the third quarter of 1976, primary stabilized in June 1979, and partially isolated in December 1982.

Based on analytical results of core samples taken in July 2001, the HDW model, and process history, one sludge type [R1 (REDOX)], and one saltcake type (S1-SltCk) were identified in SST S-112 (LA-UR-96-3860). The SST S-112 baseline was updated to a total waste volume of 1895 kL (501 kgal) calculated from the October 1, 2001, automated ENRAF measurement of 481 cm (189.5 in.). After viewing an in-tank digital video disc recorded October 10, 2001, the ENRAF probe was determined to be in a hole near the center of the tank. Because ENRAF measured the waste level by the surface (the bottom of the hole) with which it came into contact, the volume of waste was underestimated. In January 2002, the BBI was updated and the waste volume was recalculated based on two core samples taken from the July 2001 core sample event and an analysis of the tank waste profile. The more accurate estimate of tank waste volume was 2354 kL (622 kgal).

7.3 INVENTORY DERIVATION

This section describes the derivation of SST S-112 inventory based on the BBI methodology and presents the data. Table 7-1 shows a chronology of inventory changes in SST S-112 before and after the retrieval demonstration.

As discussed in Section 7.2, the BBI was updated on January 1, 2002, and the calculated waste volume in SST S-112 at that time was estimated at 2,354 kL (622 kgal). A sludge volume of 23 kL (6 kgal) was estimated using the HDW model, with the assumption that the sample constituents used in the sludge templates represent both solids and interstitial liquid. Because the waste consists of only sludge and saltcake, the saltcake volume was 2,331 kL (616 kgal) = 2,354 kL – 23 kL. The volume of liquid in the saltcake was 290 kL (77 kgal), obtained from liquid level measurement and the assumed average porosity of the saltcake. Therefore, the saltcake solids volume was 2,041 kL (539 kgal) = 2,331 kL – 290 kL.

There was no waste transfer between January 1 and July 1, 2002. Between July 1, 2002, and January 1, 2003, S-112 underwent saltwell pumping, with an estimated 29 kL (8 kgal) of liquid removed [see Tank Waste Information Network System (TWINS), Sample Analysis, Tank Transfers (current), http://twins.pnl.gov/data/datamenu.htm]. The total tank waste volume was therefore 2,325 kL (614 kgal) = 2,354 kL – 29 kL, and the saltcake liquid volume became 261 kL (69 kgal) = 290 kL – 29 kL. There was no retrieval activity between January 1 and September 26, 2003; hence the waste volume at the start of the retrieval demonstration was 614 kgal.

Table 7-1. Chronology of SST S-112 Inventory Changes.

Date/Event	Inventory
8/1/2000 BBI inventory.	Waste volume 1,980 kL (523 kgal)
10/1/2001 Waste volume calculation based on ENRAF measurement (ENRAF was in a hole)	Waste volume 1,895 kL (501 kgal)
1/1/2002 BBI update, more accurate volume calculation based on core samples and waste profile	Waste volume 2,354 kL (622 kgal) Sludge 23 kL (6 kgal) Saltcake 2,331 kL (616 kgal) Saltcake liquid 290 kL (77 kgal) Saltcake solid 2,041 kL (539 kgal)
1/1/2002–7/1/2002 No waste transfer	Unchanged
7/1/2002–1/1/2003 Saltwell pumping removed 29 kL (8 kgal) liquid. BBI updated.	Waste volume 2,325 kL (614 kgal) Sludge 23 kL (6 kgal) Saltcake 2,302 kL (608 kgal) Saltcake liquid 261 kL (69 kgal) Saltcake solid 2,041 kL (539 kgal)
1/1/2003–9/26/2003 No waste transfer	Unchanged
9/26/2003–5/17/2005 Retrieval demonstration	Varied
5/17/2005 Retrieval demonstration reached limit of technology and stopped.	Waste volume 118 kL (31 kgal) Supernatant 8 kL (2 kgal) Sludge 23 kL (6 kgal) Saltcake 87 kL (23 kgal) Saltcake liquid 21 kL (6 kgal) Saltcake solid 66 kL (17 kgal)

From September 26 to October 2, 2003, retrieval was conducted by adding water to SST S-112, dissolving the saltcake, and transferring waste to DST SY-101. From October 2, 2003, to May 17, 2005, retrieval continued with waste transferred to DST SY-102. Several quarterly material balances were performed to estimate the mass of each individual constituent in the waste for the duration of this retrieval operation. Each calculation was based on the measured liquid density, volume of water added to the tank, and volume of waste transferred from the tank, with the assumption that there was no change in the sludge volume or sludge composition. This calculation was made because there was no sampling data associated with the waste transfer. The mass of the transferred constituents was estimated using the measured density, a correlation of density to concentration (RPP-14767, *Hanford Tank Waste Operations Simulator Specific Gravity Model - Derivation of Coefficients and Validation)* and the pre-retrieval interstitial liquid concentrations. The final mass of the constituents left in the tank was then determined by subtracting the transferred mass from the previous quarter's inventory dated April 1, 2005.

At the completion of the SST S-112 retrieval demonstration, the estimated total waste volume was 31 kgal and the supernatant volume was 2 kgal. The estimated saltcake volume was therefore (subtracting the sludge and supernatant from the total waste volume) 23 kgal (87 kL) = 31 - 2 - 6. Assuming the saltcake was totally saturated, the estimated volumes for saltcake liquid was 6 kgal (21 kL) and the saltcake solid was 17 kgal (66 kL). Because the solid-liquid distribution of the constituents was not well known, and most of the constituents reside in the saltcake solid, the concentration of constituents (activity of radionuclides and mass of chemicals) was calculated based on the assumption that all constituents were distributed within the saltcake solid. The resulting inventories, obtained through multiplying those concentrations by the saltcake solid volume, were then used as input to the risk assessment.

7.4 RISK ASSESSMENT SCOPE

In HFFACO Appendix I, Section 2.1.7, *Retrieval Data Report*, one of the requirements for the RDR is to include an updated post-retrieval risk assessment. As noted in letter 05-TPD-057, "Notice of Completion of Hanford Federal Facility Agreement and Consent Order (HFFACO) Milestone M-45-03C, 'Complete Full Scale Saltcake Waste Retrieval Technology Demonstration at Single-Shell Tank 241-S-112'," SST S-112 has been retrieved to the limits of the saltcake dissolution technology but retrieval is not complete. This SST S-112 demonstration RDR includes an interim assessment of risks associated with the residual waste after the demonstration. An updated risk assessment will be submitted upon completion of the SST S-112 retrieval to fulfill the requirement in HFFACO Appendix I.

The SST S-112 retrieval demonstration leaves 4,144 ft^3 of residual waste in the tank. This section describes an interim risk assessment performed to evaluate the current tank condition.

The risk assessment for the SST S-112 residual waste compares the long-term human health risk calculated from the current inventory against the risk reported in RPP-21596, in which the SST S-112 residual waste is assumed to meet the HFFACO residual limit of 360 ft^3. Because RPP-21596 estimates the risks by tank rows (see discussion in Section 7.8.2), a comparison is also made between the tank row in SSTs S-110, S-111, and S-112 in which every tank contains 360 ft^3, and the same tank row in which SSTs S-110 and S-111 contain 360 ft^3 while SST S-112 contains 4,144 ft^3. (See tank row configuration in Figure 4-1.)

Sections 7.5 through 7.7 describe the comparison of SST S-112 tank inventories between the two residual waste volumes—the "pre-retrieval" assumption of reaching 360 ft^3 reported in RPP-21596 and the "post-retrieval" after the technology demonstration leaving 4,144 ft^3 in the tank. The effects of these inventories on long-term human health risks are also presented.

7.5 INVENTORY COMPARISON

For pre- and post- retrieval comparison of risk, the SST S-112 BBI information from two different points in time was used. The pre-retrieval risk assessment for SST S-112 described in RPP-21596 assumes that the entire tank will be retrieved to 360 ft^3. The inventory of the waste volume was calculated using data from the document RPP-20420, *241 S-SX Waste Management Area Inventory Data Package*, and the Hanford Tank Waste Operations Simulator (HTWOS) model run BCR-04-001 11-20-2003. The HTWOS model is a model that sequentially retrieves waste from all the tanks, leaving the maximum allowable in each tank (360 ft^3 or 30 ft^3). The HTWOS model used the BBI inventory prior to retrieval as its starting composition prior to retrieval. To determine the residual inventory, the model assumes that the saltcake and sludge solids of the entire tank waste are completely mixed with water and uses wash factors for each BBI constituent in the solids to calculate the inventory of individual constituents at the completion of tank retrieval.

The SST S-112 retrieval demonstration did not retrieve waste to less than 360 ft^3. Because the residual waste volume of 4,144 ft^3 was much greater than 360 ft^3, the HTWOS model was not used for estimating the residual waste inventory. Instead, the inventory calculated in the BBI (based on direct in-tank measurement of the waste volume) was used. The inventory derived from this method was used as input to calculate the risks of the 4,144 ft^3 residual waste at completion of the retrieval demonstration.

The ability to accurately predict the residual composition by applying either of these methods will not be known until the waste is sampled. However, both methods used the best available information at the time the methods were applied.

Table 7-2 provides a comparison of pre-retrieval and post-retrieval inventories of SST S-112 constituents—activity (curie content) of radionuclides and mass of chemicals—being used for the risk assessment. Comparison is presented as the ratio of the two inventories for each constituent. Note that a number of constituents in the 360 ft^3 residual waste appear higher than those in the 4,144 ft^3 residual waste, mainly because of using different inventory derivation methods.

Table 7-2. Comparison of SST S-112 Residual Waste Inventories. (3 sheets)

Isotope/ CASRN	Constituent	Units	Pre-Retrieval (estimated 360 ft^3)	Post-Retrieval (actual 4,144 ft^3)	Pre-Retrieval/ Post-Retrieval Ratio
^{3}H	Tritium	Ci	1.60E-01	4.95E-01	0.32
^{14}C	Carbon-14	Ci	5.83E-03	2.56E+01	2.28E-4
^{59}Ni	Nickel-59	Ci	9.61E-01	9.19E+00	0.10
^{60}Co	Cobalt-60	Ci	5.39E+00	2.91E-02	185.32
^{63}Ni	Nickel-63	Ci	8.93E+01	8.41E+02	0.11
^{79}Se	Selenium-79	Ci	3.36E-03	1.48E-03	2.27
^{90}Sr	Strontium-90	Ci	7.32E+03	9.59E+04	0.08
^{90}Y	Yttrium	Ci	7.32E+03	9.59E+04	0.08
^{93m}Nb	Niobium-93m	Ci	3.69E+00	2.15E+01	0.17
^{93}Zr	Zirconium-93	Ci	4.54E+00	2.58E+01	0.18
^{99}Tc	Technetium-99	Ci	5.81E-01^{a}	5.62E-01	1.03
^{106}Ru	Ruthenium-106	Ci	1.60E-05	9.90E-06	1.62
^{113m}Cd	Cadmium-113m	Ci	1.97E+01	7.94E+01	0.25
^{125}Sb	Antimony-125	Ci	7.18E+00	1.95E+01	0.37
^{126}Sn	Tin-126	Ci	6.71E-01	3.16E+00	0.21
^{129}I	Iodine-129	Ci	3.17E-04	3.14E-01	0.0010
^{134}Cs	Cesium-134	Ci	2.01E-03	3.08E-05	65.29
^{137}Cs	Cesium-137	Ci	5.70E+02	2.57E+03	0.22
^{137m}Ba	Barium-137 m	Ci	5.39E+02	2.42E+03	0.22
^{151}Sm	Samarium-151	Ci	3.73E+03	1.70E+04	0.22
^{152}Eu	Europium-152	Ci	5.45E-01	3.54E+00	0.15

Table 7-2. Comparison of SST S-112 Residual Waste Inventories. (3 sheets)

Isotope/ CASRN	Constituent	Units	Pre-Retrieval (estimated 360 ft^3)	Post-Retrieval (actual 4,144 ft^3)	Pre-Retrieval/ Post-Retrieval Ratio
^{154}Eu	Europium-154	Ci	1.70E+01	3.36E-01	50.66
^{155}Eu	Europium-155	Ci	1.47E+01	1.13E-01	129.80
^{226}Ra	Radium-226	Ci	3.01E-07	2.31E-04	0.00
^{228}Ra	Radium-228	Ci	7.01E-03	2.48E-02	0.28
^{227}Ac	Actinium-227	Ci	5.33E-04	2.83E-03	0.19
^{229}Th	Thorium-229	Ci	3.13E-04	1.83E-03	0.17
^{231}Pa	Protactinium-231	Ci	2.79E-05	6.54E-03	0.0043
^{232}Th	Thorium-232	Ci	9.74E-05	1.25E-03	0.08
^{232}U	Uranium-232	Ci	1.16E-02	1.32E-01	0.09
^{233}U	Uranium-233	Ci	4.22E-02	5.55E-01	0.08
^{234}U	Uranium-234	Ci	5.97E-02	4.81E-01	0.12
^{235}U	Uranium-235	Ci	2.62E-03	2.02E-02	0.13
^{236}U	Uranium-236	Ci	1.09E-03	1.31E-02	0.08
^{238}U	Uranium-238	Ci	5.88E-02	4.56E-01	0.13
^{237}Np	Neptunium-237	Ci	1.16E-01	1.38E+00	0.08
^{238}Pu	Plutonium-238	Ci	1.05E-01	1.10E+00	0.10
^{239}Pu	Plutonium-239	Ci	5.44E+00	4.85E+01	0.11
^{240}Pu	Plutonium-240	Ci	8.38E-01	8.61E+00	0.10
^{241}Pu	Plutonium-241	Ci	5.17E+00	4.47E+01	0.12
^{242}Pu	Plutonium-242	Ci	3.73E-05	4.08E-04	0.09
^{241}Am	Americium-241	Ci	6.48E+00	7.98E+01	0.08
^{243}Am	Americium-243	Ci	1.99E-04	5.87E-03	0.03
^{242}Cm	Curium-242	Ci	5.12E-04	1.08E-03	0.47
^{243}Cm	Curium-243	Ci	1.02E-05	1.83E-05	0.56
^{244}Cm	Curium-244	Ci	2.31E-05	4.53E-04	0.05
7429-90-5	Aluminum	kg	4.47E+02	7.61E+03	0.06
7440-69-9	Bismuth	kg	2.15E+01	1.38E+02	0.16
7440-70-2	Calcium	kg	3.58E+01	1.98E+02	0.18
16887-00-6	Chloride	kg	4.29E+00	9.12E+01	0.05
18540-29-9	Chromium	kg	6.55E+02	1.21E+02	5.44
7782-41-4	Fluoride	kg	4.10E+00	6.74E+01	0.06
7439-89-6	Iron	kg	1.12E+02	1.15E+03	0.10
7439-91-0	Lanthanum	kg	1.11E+01	1.17E+02	0.09
7439-92-1	Lead	kg	2.48E+01	4.98E+01	0.50
7439-96-5	Manganese	kg	2.39E+01	2.41E+02	0.10
7439-97-6	Mercury	kg	1.81E-01	2.74E+00	0.07
7440-02-0	Nickel	kg	1.41E+01	5.76E+01	0.24
14797-65-0	Nitrite	kg	3.87E+01	1.29E+03	0.03
14797-55-8	Nitrate	kg	1.02E+03	4.56E+03	0.22
338-70-5	Oxalate	kg	Not reported	4.58E+03	0.00

Table 7-2. Comparison of SST S-112 Residual Waste Inventories. (3 sheets)

Isotope/ CASRN	Constituent	Units	Pre-Retrieval (estimated 360 ft^3)	Post-Retrieval (actual 4,144 ft^3)	Pre-Retrieval/ Post-Retrieval Ratio
14265-44-2	Phosphate	kg	1.24E+02	8.25E+03	0.02
7440-09-7	Potassium	kg	1.44E+01	2.50E+01	0.58
7440-21-3	Silicon	kg	2.31E+02	4.65E+03	0.05
7440-23-5	Sodium	kg	9.61E+02	1.27E+04	0.08
14808-79-8	Sulfate	kg	5.87E+02	3.73E+04	0.02
7440-24-6	Strontium	kg	2.61E+00	3.94E+01	0.07
7440-29-1	Thorium	kg	Not reported	1.14E+01	0.00
7440-61-1	Uranium	kg	1.76E+02	1.37E+03	0.13
7440-67-7	Zirconium	kg	1.33E-01	2.38E+00	0.06
	Aroclors (total PCB)	kg	Not reported	1.05E-02	0.00

[a] This is the inventory value used in the risk assessment calculations in RPP-21596 and represents the ^{99}Tc inventory as calculated by the BBI templates developed from the HDW Model (LA-UR-96-3860) in 1997, and the Hanford Tank Waste Operations Simulator ^{99}Tc wash factors presented in RPP-21271, *Justification for Updating the Technetium-99 Wash Factors for the S and SX Tank Farms.* The ^{99}Tc value reported in Table 3-7 of RPP-21596 (1.16 Ci) was a typographical error. The inventory in the "Post-Retrieval" column of this table represents the value calculated by the BBI templates developed in the 2004 update of the HDW model (RPP-19822, *Hanford Defined Waste Model*) and the wash factors presented in RPP-RPT-23329, *Updated Technetium-99 Wash Factors for Hanford Site Tank Wastes.*
CASRN= Chemical Abstracts Service Registry Number.

7.6 CONSTITUENTS OF POTENTIAL CONCERN

Constituents of potential concern (COPC) are those contaminants that have the potential to contribute significantly to the risk at the site surrounding SST S-112. Identification of COPCs is an important process because it determines the list of constituents for which preliminary remediation goals for the site are developed. Evaluation of the COPCs also supports tank closure activities to meet the Washington Administrative Code (WAC) 173-303-610(2) closure performance standards for human health and the environment.

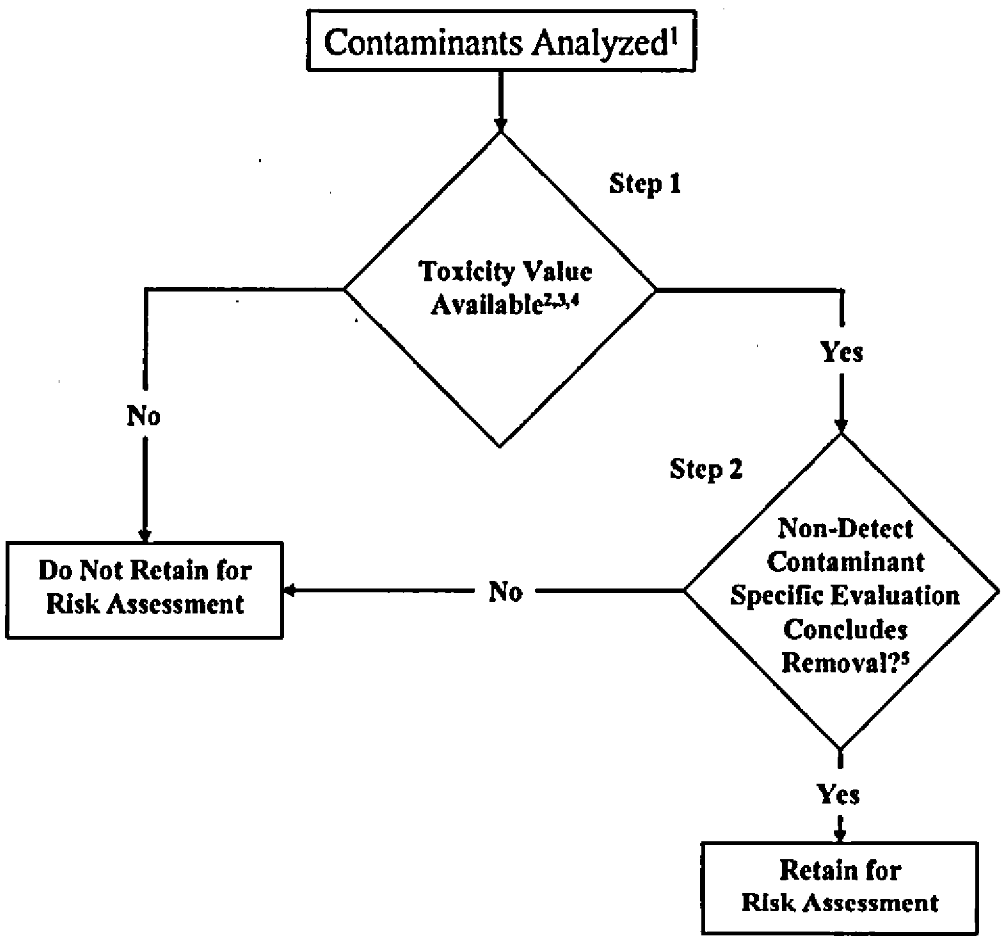
When analytical data is available from residual waste samples, this data is evaluated in the COPC screening process shown in Figure 7-1. Step one in the screen process requires that if a toxicity value is available, the constituent will be considered in the risk assessment.

The SST S-112 retrieval demonstration did not include residual waste sampling. Nevertheless, all radionuclides and all hazardous chemicals in the BBI for SST S-112 have been considered in the risk assessment. A description of the analysis is given in Sections 7.7 and 7.8. Results of the risk assessment for the COPCs are provided in Tables 7-5 (for radionuclides) and 7-6 (for chemicals).

7.7 EFFECT OF SOURCE TERM ON LONG-TERM HUMAN HEALTH RISKS

This section provides a comparison of the long-term human health risks from SST S-112, using the residual waste volumes of 360 ft^3 and 4,144 ft^3. The pre-retrieval risk assessment for the estimated 360 ft^3 residual waste uses the inventory and contaminant releases model described in the document RPP-21596 (see Section 7.5). This diffusion model simulates the release from stabilized (grouted) waste. The grout is expected to limit water flow though the contaminants to levels such that the advective transport of the waste is negligible. In the absence of advection transport through the waste source, the release occurs as a function of time, the diffusion coefficient of the contaminant in the waste form, and the length through the grout which the contaminants must traverse. The risk calculations also include an assumption that there is an 8,000-gal retrieval leak.

Figure 7-1. Screening Process for Constituents of Potential Concern.



Footnotes

[1]Contaminants analyzed and screened are identified in RPP-PLAN-23827, *Sampling and Analysis Plan for Single Shell Tanks Component Closure*

[2]Toxicity values should be obtained from IRIS, ORNL-RAIS, HEAST-rad, HEAST-nonrad, EPA Region 9 PRGs, and scientific literature. Priority is given to IRIS; however, when values are not available in IRIS the other databases should be used. Use of scientific literature is acceptable when approved by Ecology.

[3]Detects obtained by using modified EPA SW-846 methods performed in accordance with requirements of Wiemers and others (*Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project*, PNNL-12040, Rev. 0-, Pacific Northwest National Laboratory, Richland Washington, USA, December 1998). The methods were developed for organic and inorganic chemical analysis in the tank matrices.

[4]Contaminants that are not detected but retained for the risk assessment should be included at half of their detection levels.

[5]Non-detected contaminants will be further screened to determine removal of contaminant to the cumulative risk by the risk assessment group based on consideration of information including but not limited to historical process knowledge, manufacturing data, toxicity value source information, and potential for formation as a degradation product. Although, the contaminant may be excluded from the cumulative, the ILCR/Dose/HI for that individual contaminant will be included.

The SST S-112 retrieval demonstration left behind a much larger volume (4,144 ft^3, approximately 10 to 12 inches at the tank bottom) of residual waste than 360 ft^3 (approximately 1 inch at the tank bottom). Advective transport of the waste within this volume is more likely, and the more conservative advection model of contaminant release is used in the post-retrieval risk assessment. This model represents the release of contaminants from unstabilized (non-grouted) waste, in which the contaminants exit the source at a rate determined by the flow of water and the amount of mixing that occurs within the source. The risk calculations also include an assumption that the retrieval leak is negligible, based on the discussion in Section 4.4. Further explanation of the advection and diffusion release models is contained in RPP-17209, *Modeling Data Package for an Initial Assessment of Closure for S-SX Tank Farms.*

The key parameters affecting the risk assessment are retrieval leak, residual waste risk metrics, and residual waste effects on drinking water standards. Because SST S-112 saltcake retrieval demonstration retrieval leakage is considered negligible, the following sections present estimates of the risk metrics and effects on drinking water standards from residual wastes only.

7.7.1 Residual Waste Risk Metrics

Table 7-3 presents the cumulative Incremental Lifetime Cancer Risk (ILCR), Hazard Index (HI), and radiological drinking water dose from residual waste inventories for the industrial and residential receptors. These metrics are estimated using peak modeled groundwater contaminant concentrations from the SST S-112 residual waste at the WMA S-SX fence line.

Table 7-3. Cumulative ILCR, HI, and Radiological Drinking Water Dose from Peak Groundwater Concentration Related to Residual Waste Volume in SST S-112.

	Industrial Receptor			Residential Receptor		
Metric	Pre-Retrieval (360 ft^3)	Post-Retrieval (4,144 ft^3)	Ratio	Pre-Retrieval (360 ft^3)	Post-Retrieval (4,144 ft^3)	Ratio
Radioactive chemicals ILCR[a] (unitless)	3.0E-07	6.7E-05	2.23E+02	7.1E-06	4.3E-04	6.06E+01
Nonradioactive chemicals ILCR[b] (unitless)	3.6E-7	3.1E-07	8.61E-01	8.4E-07	7.2E-07	8.57E-01
HI[c] (unitless)	9.4E-2	1.1E-01	1.17E+00	5.6E-01	6.5E-01	1.16E+00

Metric	Pre-Retrieval (360 ft^3)	Post-Retrieval (4,144 ft^3)	Ratio
All pathways farmer dose[d] (mrem/yr)	4.3E-02	4.5E+01	1045

Note: The performance objectives in the following apply to the WMA S-SX, not just a single component of the WMA, such as SST S-112.

[a] ILCR target value is 1.0 E-04 to 1.0 E-06 for radioactive constituents (EPA/540/R-99/006 *Radiation Risk Assessment at CERCLA Sites: Q & A Directive* 9200.4-31P)

[b] ILCR target value is <1.0 E-05 for the cumulative total on nonradioactive constituents; an individual contaminant cannot exceed 1.0 E-06

[c] Noncarcinogenic HI is <1.0

[d] The All-Pathways Farmers target value is 25 mrem/year, DOE O 435.1, *Radioactive Waste Management.*

As can be seen from Table 7-3, the range in ratios between the pre-retrieval assumption of 360 ft^3 and the post-retrieval volume of 4,144 ft^3 varies over several orders of magnitude depending on the metric. The reasons for this variation are the following:

a. **Contaminants that Drive the Risk:** In the pre-retrieval risk assessment (RPP-21596) for ILCR-rad and dose metrics, in which the residual waste is assumed to be 360 ft^3, ^{99}Tc is the primary contaminant that accounts for 97 % of the risk. In the post-retrieval residual waste of 4,144 ft^3, ^{129}I accounts for 59%, followed by ^{14}C at 39%, and ^{99}Tc at 2%.

b. **Advection- vs. Diffusion- Dominated Release Model:** In the pre-retrieval risk assessment, releases from the contaminants are controlled by diffusion because the residual waste (360 ft^3) is less than 1 in. thick and that residue will be covered with grout. The post-retrieval residual waste (4,144 ft^3) is approximately 10 to 12 in. thick, without a stabilizing grout or a grout cap; therefore the more conservative advection-dominated release model was used. Estimated concentrations from the advection-dominated model are approximately 4.6 times higher than those from the diffusion-dominated model when applied to the HFFACO residual waste volume (360 ft^3).

c. **Exposure Pathways:** Exposure pathways are related to risk-driving contaminants. In the pre-retrieval risk assessment, ^{99}Tc is the principal risk-driving contaminant; the principal exposure pathway for this radionuclide is consumption of garden vegetables, followed by drinking water. In the post-retrieval risk assessment, ^{129}I and ^{14}C are the risk drivers; the principal exposure pathway is drinking water, followed by consumption of vegetables (HNF-SD-WM-TI-707, Appendix D).

7.7.2 Residual Waste Effects on Drinking Water Standards

Estimated long-term groundwater quality effects for each residual inventory are compared to the primary drinking water standards maximum contaminant levels (MCL) in Table 7-4. The differences observed in this table are for the same reasons given in Table 7-3.

7.8 CUMULATIVE EFFECTS OF REPRESENTATIVE COMPONENT SOURCE TERMS

Section 7.7 provides a comparison of the effects of source term on long-term human health risks between residual waste volumes 360 ft^3 and 4,144 ft^3. Key parameters analyzed include the cumulative ILCR, HI, and radiological drinking water dose for the industrial and residential receptors. This section assesses the cumulative contribution of source terms to those key parameters by examining four risk patterns in the industrial worker and the residential scenarios: (1) SST Row S-110 to S-112 with residual volumes 360 ft^3, (2) the same SST Row in which SST S-110 and S-111 have 360 ft^3 and S-112 has 4,144 ft^3, (3) SST S-112 with residual volume 360 ft^3; and (4) SST S-112 with residual volume 4,144 ft^3. The scenarios are chosen for purposes of comparison and do not include all scenarios pertinent to closure of SST S-112. Additionally, this section presents the estimated cumulative effect of each constituent (radionuclides and chemicals) in the residual volume of 4,144 ft^3.

Table 7-4. Comparison of Groundwater Impact from SST S-112 Between Residual Waste Volume of 360 ft^3 and 4,144 ft^3.

Constituent	Pre-Retrieval (360 ft^3)	Post-Retrieval (4,144 ft^3)	Drinking Water Standard (MCL)
Carbon-14	0.015 pCi/L	3,400 pCi/L	2,000 pCi/L[a]
Technetium-99	21.1 pCi/L	94.0 pCi/L	900 pCi/L[a]
Iodine-129	0.012 pCi/L	53.1 pCi/L	1 pCi/L[a]
Total radiological dose	0.014 mrem/yr	219 mrem/yr	4 mrem/yr[b]
Chromium	0.024 mg/L	0.020 mg/L	0.10 mg/L[c]
Nitrate	0.038 mg/L	0.77 mg/L	45 mg/L[d]
Nitrite	0.0024 mg/L	0.22 mg/L	3 mg/L[d]

[a] The radionuclide concentration shown is the "C4" concentration, which is the concentration of the individual nuclide in drinking water that would result in an annual dose of 4 mrem/yr, using the target organ dose methodology specified by the Washington State Environmental Policy Act.
[b] Target organ dose.
[c] MCL = maximum contaminant level; MCL for chromium is for total chromium, not hexavalent chromium.
[d] Converted from EPA standard value for nitrogen.

7.8.1 Assumptions

The base case evaluated for SST S-112 in RPP-21596 (pre-retrieval) includes contribution to risk metrics from residual tank waste after retrieval to 360 ft^3 and an assumed 8000-gal retrieval leak. This section focuses on the changes to the base-case risk assessment caused by the inventory from 4,144 ft^3 at the end of the retrieval demonstration (post-retrieval).

The pre-retrieval risk assessment assumes that plumes emanating from one row of tanks along the same flow path within the WMA do not intersect or interact with another by the time the plume arrives at the WMA fence line. This assessment also assumes that the row with the highest impact defines the maximum risk associated with the WMA. Additionally, the impact is divided into two source types: those that occur shortly after closure (past tank leaks, past ancillary equipment leaks, and potential retrieval leaks) and those that are not expected to occur for thousands of years into the future (tank residuals). Section 7.8.2 provides an estimate of the impacts from SST S-112 as well as from SST row S-110 to SST S-112 based on these assumptions.

7.8.2 Radiological Incremental Lifetime Cancer Risk

Figure 7-2 shows the cumulative contribution to radiological incremental lifetime cancer risk (ILCR-rad) for the industrial worker scenario between the different residual inventories. The performance objective for ILCR-rad is less than 1.0 E-04 to 1.0 E-06 (EPA/540/R-99/006, *Radiation Risk Assessment at CERCLA Sites: Q & A Directive* 9200.4-31P) for WMA S-SX. The following four curves are shown in Figure 7-2.

a. **SST Row S-110 to S-112 Pre-Retrieval:** The impact after retrieving this row of tanks to 360 ft^3 of residual waste (pre-retrieval assumption) is shown by the solid line with square symbols. This is the cumulative ILCR-rad curve taken from Figure 6-2 of RPP-21596. The sources included in this curve are the potential retrieval leaks and tank residuals. The peak ILCR-rad for this curve is 7.9E-05, which is due to potential retrieval leaks.

The peak ILCR-rad at the time (year 4901) tank residuals peak along this row is 5.9E-07; the ICLR-rad for residuals alone is 5.6 E-07.

b. **SST Row S-110 to S-112 Post-Retrieval:** The ILCR-rad impacts of retrieving SSTs S-110 and S-111 to 360 ft^3 and SST S-112 to 4,144 ft^3 are shown by the dashed line with triangles. The sources included in this curve are tank residuals and the potential retrieval leaks for SSTs S-110 and S-111 but no retrieval leak for SST S-112. The peak ILCR-rad for this curve is 5.8E-05, which is due to potential retrieval leaks; the peak for tank residuals and potential retrieval leaks at the time (year 4041) tank residuals peak along this row is 6.75E-05; the ICLR-rad for residuals alone is 6.70E-05.

c. **SST S-112 Pre-Retrieval:** The ILCR-rad impact after retrieving tank SST S-112 to 360 ft^3 is shown by the dashed line with the gradient symbol. This is a cumulative curve showing an 8000-gal retrieval leak along with the impact from tank residuals. The ILCR-rad peak value in year 2061 is 2.1E-05 due to the hypothetical 8000-gal retrieval leak during retrieval operations. The peak ILCR-rad at the time (year 4901) tank residuals peak along this row is 3.01E-07, with the residuals alone being 3.01E-07.

d. **SST S-112 Post-Retrieval:** The ILCR-rad impacts of SST S-112 with a waste residual volume of 4,144 ft^3 is shown by the dashed dotted line with left-pointing triangles. Since the volume of a possible retrieval leak was considered negligible (see Section 4.4), this curve represents only the residual waste remaining in the tank. The peak ILCR-rad from tank residuals alone is 6.7E-05 in year 4041.

Figure 7-2. Incremental Lifetime Cancer Risk—Comparison Between Pre-Retrieval (assume reaching HFFACO limit of 360 ft^3) and Post-Retrieval (4,144 ft^3) for the Industrial Land Use Scenario.

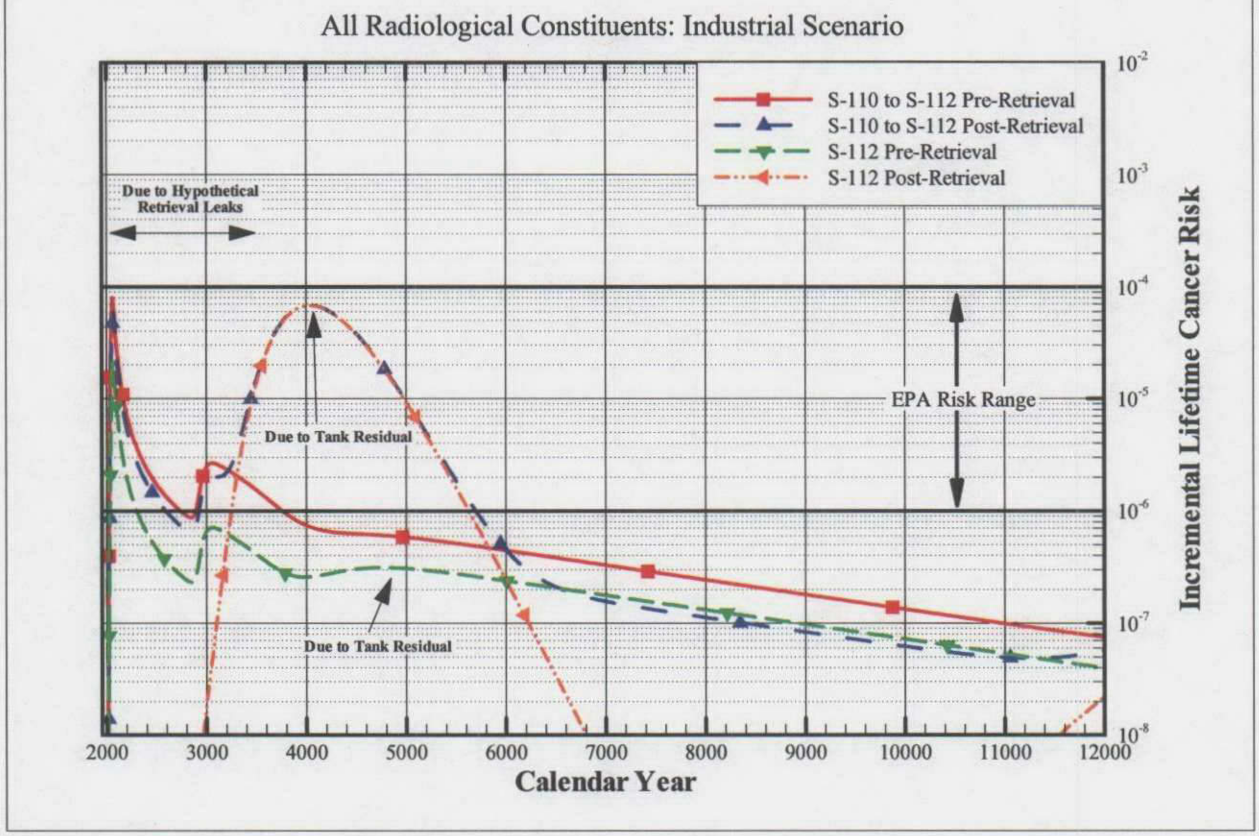
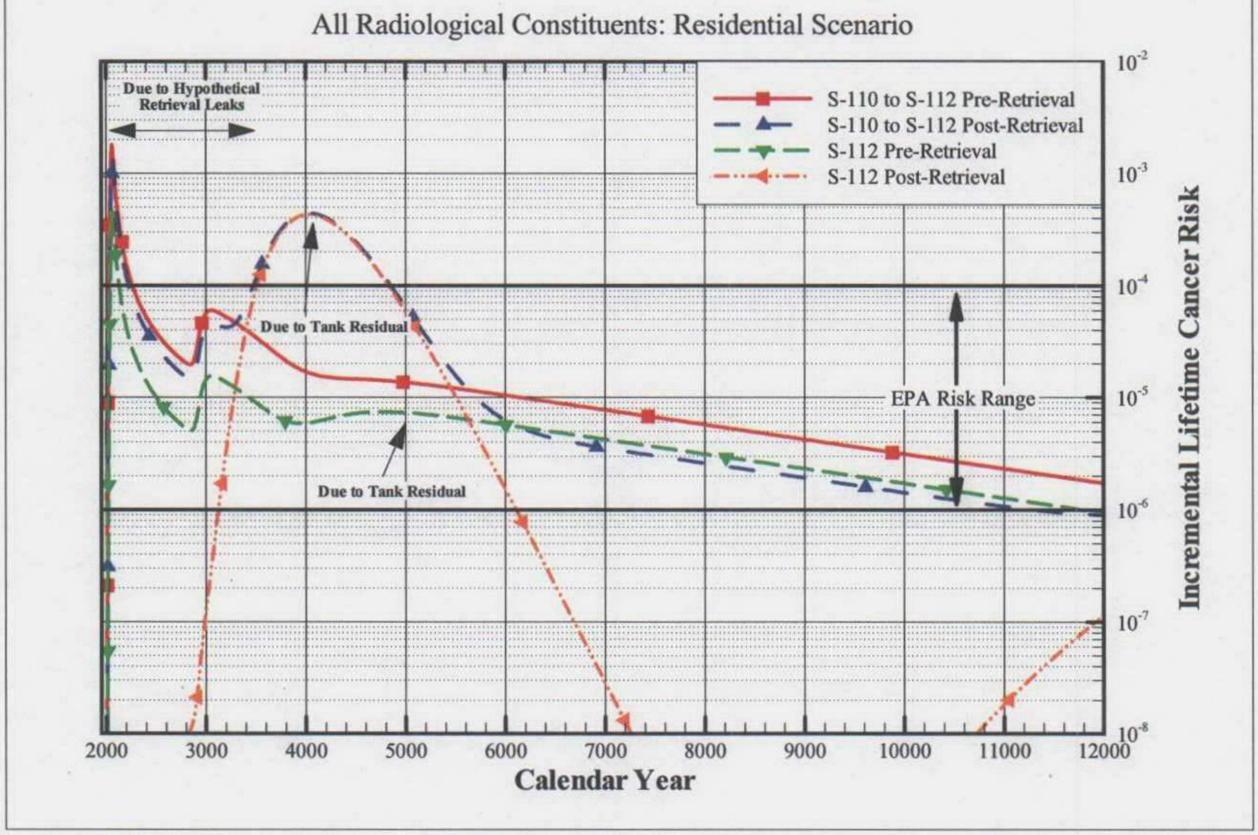


Figure 7-3 shows the residential scenario for the same four curves. Although the residential scenario shows the same risk pattern as the industrial scenario, the risk is approximately 6.5 times higher, representing greater use of the groundwater by the residential receptor.

Figure 7-3. Incremental Lifetime Cancer Risk—Comparison Between Pre-Retrieval (assume reaching HFFACO limit of 360 ft³) and Post-Retrieval (4,144 ft³) for the Residential Land Use Scenario.



7.8.3 Hazard Index

Figure 7-4 shows the cumulative contribution to HI for the industrial worker for the different residual volumes. The performance objective for HI is less than 1.0 for WMA S-SX. In Figure 7-4 the following four curves are shown:

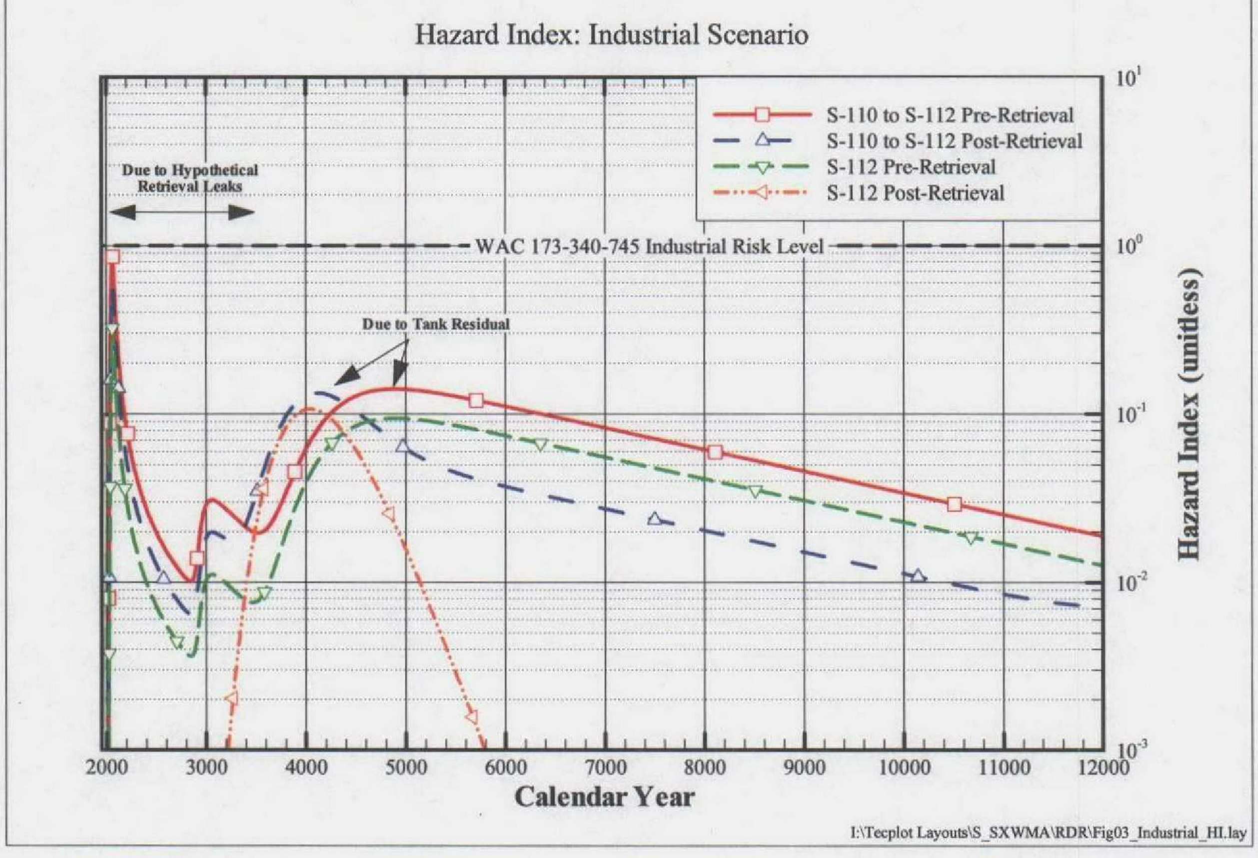
a. **SST Row S-110 to S-112 Pre-Retrieval:** The HI impact after retrieving this row of tanks to 360 ft^3 is shown by the solid line with square symbols. This is the cumulative HI curve shown in Figure 6-4 of RPP-21596. The sources included in this curve are the potential retrieval leaks and tank residuals. The peak HI for this curve is 0.91, which is due to potential retrieval leaks. The peak HI at the time (year 4901) tank residuals peak along this row is 0.14. The HI for tank residuals alone at this time is also 0.14 because the contributions to HI from tank retrieval leaks are very small by the time the peaks related to residuals arrive.

b. **SST Row S-110 to S-112 Post-Retrieval:** The HI impact after retrieving SSTs S-110 and S-111 to 360 ft^3 and SST S-112 to 4,144 ft^3 is shown by the dashed line with triangles. The sources included in this curve are the potential retrieval leaks for SSTs S-110 and S-111 and tank residuals for all three tanks. The HI peak due to potential retrieval leaks is 0.58. The peak HI at the time (year 4041) tank residuals peak along this row is 0.13.

c. **SST S-112 Pre-Retrieval:** The HI impact after retrieving SST S-112 to 360 ft^3 is shown by the dashed line with the gradient symbol. This is a cumulative HI curve showing an 8000-gal retrieval leak along with the impact from tank residuals. The peak HI value in year 2061 is 0.33 due to the hypothetical 8000-gal retrieval leak occurring during retrieval operations. The peak HI at the time tank residuals peak along this row (year 4901) is 0.09.

d. **SST S-112 Post-Retrieval:** The HI impact after retrieving SST S-112 to 4,144 ft^3 is shown by the dashed dotted line with left-pointing triangles. This curve represents only the residual waste remaining in the tank because the volume of a possible retrieval leak was considered negligible. The peak HI from tank residuals is 0.11 in the year 4041.

Figure 7-4. Hazard Index – Comparison Between Pre-Retrieval (assume reaching HFFACO limit of 360 ft^3) and Post-Retrieval (4,144 ft^3) for the Industrial Land Use Scenario.



7.8.4 All Pathways Farmer Dose

Figure 7-5 shows the cumulative contribution to radiological drinking water dose in the APF scenario for the different residual volumes. The performance objective for radiological drinking water dose is less than 25 mrem effective dose equivalent (EDE) per year for WMA S-SX. In Figure 7-5 the following four curves are shown:

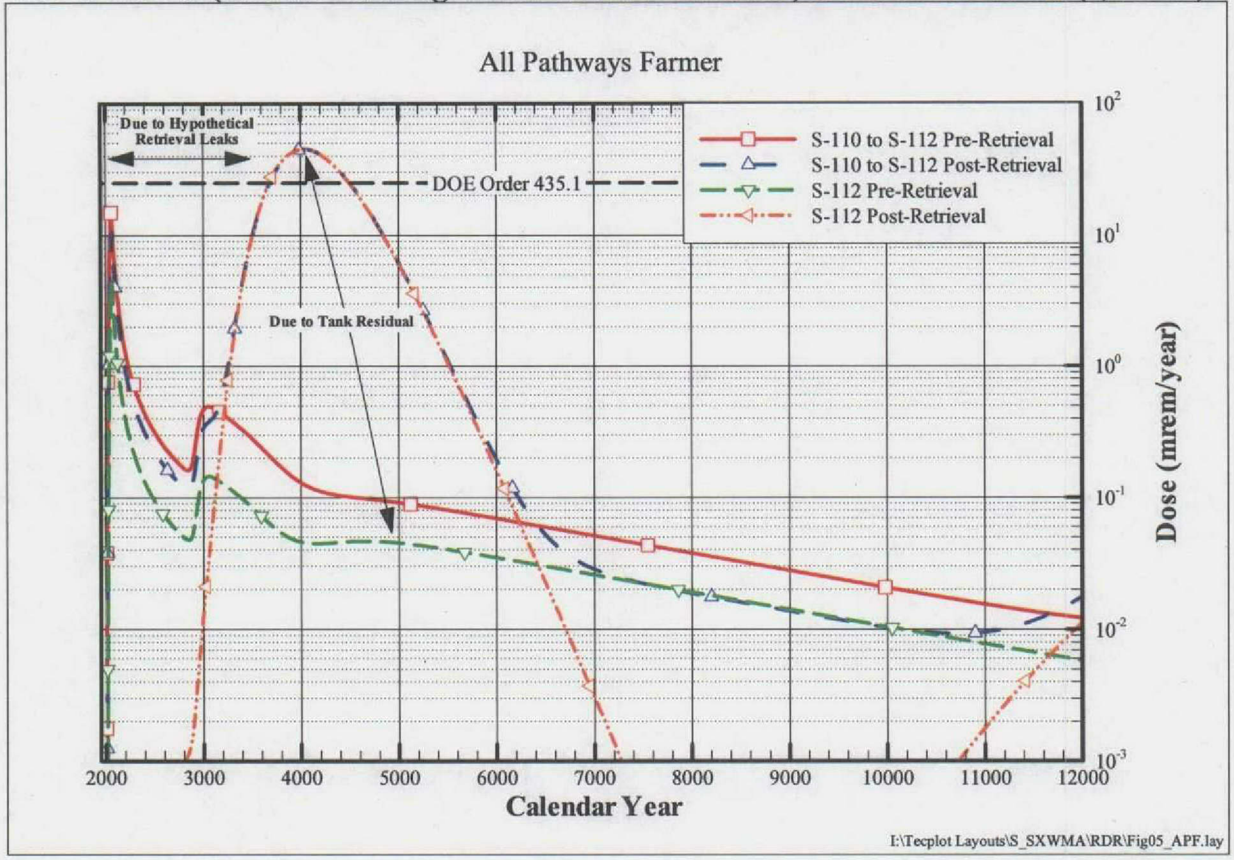
a. **SST Row S-110 to S-112 Pre-Retrieval:** The impact after retrieving this row of tanks to 360 ft^3 is shown by the solid line with square symbols. This is the cumulative APF curve shown in Figure 6-6 of RPP-21596. The sources included in this curve are the potential retrieval leaks and tank residuals. The peak APF dose for this curve is 14.8 mrem/yr, which is due to potential retrieval leaks. The peak APF dose at the time (year 4901) tank residuals peak along this row is 0.093 mrem EDE/yr and for the residuals alone the peak is 0.088 mrem EDE/yr.

b. **SST Row S-110 to S-112 Post-Retrieval:** The APF impact after retrieving SSTs S-110 and S-111 to 360 ft^3 and SST S-112 to 4,144 ft^3 is shown by the dashed line with triangles. The sources included in this curve are the potential retrieval leaks for SSTs S-110 and S-111 and residuals for all three tanks. The peak APF dose due to potential retrieval leaks is 10.5 mrem EDE/yr. The peak APF dose at the time (year 4041) tank residuals peak along this row is 44.6 mrem EDE/yr and that for tank residuals alone is 44.5 mrem EDE/yr.

c. **SST S-112 Pre-Retrieval:** The APF dose impact after retrieving SST S-112 to 360 ft^3 is shown by the dashed line with the gradient symbol. This is a cumulative curve showing an 8000-gal retrieval leak along with the impact from tank residuals. The peak APF dose is 4.33 mrem EDE/yr in year 2061 due to the hypothetical 8000-gal retrieval leak occurring during retrieval operations. The peak APF dose at the time tank residuals peak along this row (year 4901) is 0.045 mrem EDE/yr.

d. **SST S-112 Post-Retrieval:** The APF dose impact after retrieving SST S-112 to 4,144 ft^3 is shown by the dashed dotted line with left-pointing triangles. The peak APF dose from tank residuals is 44.5 mrem EDE/yr in the year 4041.

Figure 7-5. All Pathways Farmer Radiological Dose—Comparison Between Pre-Retrieval (assume reaching HFFACO limit of 360 ft^3) and Post-Retrieval (4,144 ft^3).



7.8.5 Target Organ Dose

Figure 7-6 shows the cumulative contribution to beta/photon emitters target organ drinking water dose (TODWD) for the different residual volumes. The performance objective for beta/photon emitters is less than 4 mrem/yr, which is the MCL for WMA S-SX. In this figure the following four curves are shown.

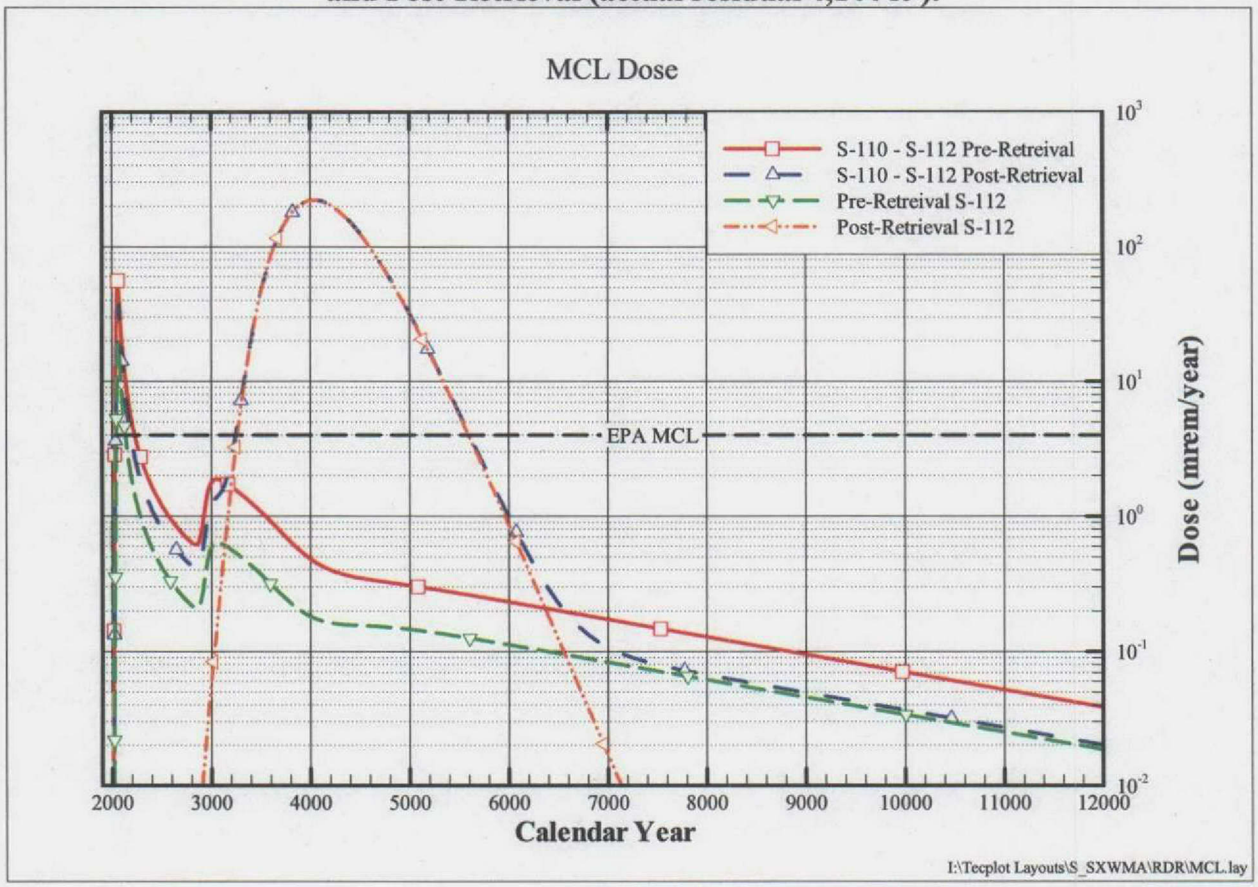
a. **SST Row S-110 to S-112 Pre-Retrieval:** The TODWD impact after retrieving this row of tanks to 360 ft^3 is shown by the solid line with square symbols. The sources included in this curve are the potential retrieval leaks and tank residuals. The peak dose for this curve is 56 mrem/yr in the year 4901, which is due to potential retrieval leaks. The APF dose in year 4901 when tank residuals peak along this row is 0.31 mrem/yr and that for the residuals alone is 0.29 mrem/yr.

b. **SST Row S-110 to S-112 Post-Retrieval:** The TODWD impact after retrieving SSTs S-110 and S-111 to 360 ft^3 and SST S-112 to 4,144 ft^3 is given as the dashed line with triangles. The sources included in this curve are the potential retrieval leaks for SSTs S-110 and S-111 and residuals for all three tanks. The peak dose due to potential retrieval leaks is 37 mrem/yr in year 2061 and that when tank residuals peak along this row is 219.9 mrem/yr in the year 4041.

c. **SST S-112 Pre-Retrieval:** The TODWD impact after retrieving SST S-112 to 360 ft^3 is shown by the dashed line with the gradient symbol. This is a cumulative curve showing an 8000-gal retrieval leak along with the impact from tank residuals. The peak dose is 19 mrem/yr yr in year 2061 due to the hypothetical 8000-gal retrieval leak occurring during retrieval operations. The peak dose when tank residuals peak along this row is 0.14 mrem/yr in the year 4901.

d. **SST S-112 Post-Retrieval:** The impact after retrieving SST S-112 to 4,144 ft^3 is shown by the dashed dotted line with left-pointing triangles. The peak dose from tank residuals is 219.8 mrem/yr in the year 4041.

Figure 7-6. Target Organ Dose (Maximum Contaminant Level Dose)—Comparison Between Pre-Retrieval (estimated residual 360 ft^3) and Post-Retrieval (actual residual 4,144 ft^3).



7.8.6 Results for Individual Constituents

This section provides data on the estimated impact of each constituent in the SST S-112 residual waste of 4,144 ft^3. Table 7-5 shows the risk for each exposure scenario per radionuclide given in the BBI. Table 7-6 provides the estimated impact of the chemicals. Each table consists of the following columns:

a. **Isotope/CASRN** is the radionuclide/ chemical abstracts service registry number.

b. **Isotope Name/Chemical** is the name of the radionuclide or chemical.

c. **Inventory** is the activity (curie) of the radionuclide or mass (kg) of the chemical as given in the BBI.

d. **Ground Water Concentration at WMA Fence Line** is the modeled concentration (RPP-21596) at the WMA S/SX fence line. Short-lived radionuclides will decay away before the contaminant can arrive at the fence line. Relatively immobile COPCs (i.e., K_d greater than 0.6 mg/L) will also result in a negligible concentration at the fence line, as they will not reach the fence line within 10,000 years.

e. K_d is the mobility factor used in the groundwater modeling for the contaminant. The smaller the K_d, the more mobile the contaminant; if the K_d is zero, the contaminant moves with the groundwater.

f. **Half-life** is the duration (in years) for the radionuclide to decay to half its activity.

g. **Incremental Lifetime Cancer Risk** for the residential and industrial exposure scenarios are defined in *Exposure Scenarios and Unit Dose Factors for Hanford Tank Waste Performance Assessments* (HNF-SD-WM-TI-707).

h. **All-Pathways Farmer Dose** is the estimated drinking water dose for the APF exposure scenario.

i. **Target Organ Dose** is the estimated drinking water dose to organs targeted by beta/photon emitters.

j. **Hazard Index** for chemicals in the residential and industrial exposure scenarios is defined in HNF-SD-WM-TI-707.

The peak value for each risk metric is calculated by summing the contribution from each contaminant at the time of the overall peak, taking into account radioactive decay. Figure 7-7 shows the relative contribution of the major risk-driving contaminants to the peak value for ILCR-rad residential scenario and for the HI residential scenario. Both residential scenarios are taken from HNF-SD-WM-TI-707.

Table 7-5. Cumulative Effects of Radionuclides in SST S-112 Residual Waste (4,144 ft^3). (2 sheets)

Isotope	Isotope Name	Inventory (Ci)	Ground Water Concentration at WMA Fence Line (pCi/L)	K_d (ml/g)	Half-Life (yr)	Incremental Lifetime Cancer Risk		Drinking Water Dose	
						Industrial Scenario[a]	Residential Scenario[a]	All Pathways Farmer[a] (mrem/yr)	Target Organ (mrem/yr)
^{3}H	Tritium	4.95E-01	<0.01[b]	0	1.23E+01	Negligible	Negligible	Negligible	Negligible
^{14}C	Carbon-14	2.56E+01	3.39E+03	0	5.73E+03	2.63E-05	1.90E-04	1.64E+01	6.78E+00
^{59}Ni	Nickel-59	9.19E+00	<0.01[b]	1	7.50E+04	Negligible	Negligible	Negligible	Negligible
^{63}Ni	Nickel-63	8.41E+02	<0.01[b]	1	1.00E+02	Negligible	Negligible	Negligible	Negligible
^{60}Co	Cobalt-60	2.91E-02	<0.01[b]	0.1	5.27E+00	Negligible	Negligible	Negligible	Negligible
^{79}Se	Selenium-79	1.48E-03	<0.01[b]	1	8.05E+05	Negligible	Negligible	Negligible	Negligible
^{90}Sr	Strontium-90 + D	9.59E+04	<0.01[b]	1	2.81E+01	Negligible	Negligible	Negligible	Negligible
^{93}Zr	Zirconium-93	2.58E+01	<0.01[b]	1	1.53E+06	Negligible	Negligible	Negligible	Negligible
^{99}Tc	Technetium-99	5.62E-01	9.44E+01	0	2.11E+05	1.30E-06	3.17E-05	1.65E-01	4.20E-01
^{106}Ru	Ruthenium-106	9.90E-06	<0.01[b]	1	1.02E+00	Negligible	Negligible	Negligible	Negligible
^{126}Sn	Tin-126	3.16E+00	<0.01[b]	1	2.46E+05	Negligible	Negligible	Negligible	Negligible
^{125}Sb	Antimony-125	1.95E+01	<0.01[b]	1	2.73E+00	Negligible	Negligible	Negligible	Negligible
^{129}I	Iodine-129	3.14E-01	5.31E+01	0	1.57E+07	3.94E-05	2.04E-04	2.79E+01	2.12E+02
^{134}Cs	Cesium-134	3.08E-05	<0.01[b]	1	2.06E+00	Negligible	Negligible	Negligible	Negligible
^{137}Cs	Cesium-137 + D	2.57E+03	<0.01[b]	1	3.00E+01	Negligible	Negligible	Negligible	Negligible
^{151}Sm	Samarium-151	1.70E+04	<0.01[b]	1	9.00E+01	Negligible	Negligible	Negligible	Negligible
^{152}Eu	Europium-152	3.54E+00	<0.01[b]	1	1.33E+01	Negligible	Negligible	Negligible	Negligible
^{154}Eu	Europium-154	3.36E-01	<0.01[b]	1	8.59E+00	Negligible	Negligible	Negligible	Negligible
^{155}Eu	Europium-155	1.13E-01	<0.01[b]	1	4.68E+00	Negligible	Negligible	Negligible	Negligible
^{226}Ra	Radium-226 + D	2.31E-04	<0.01[b]	1	1.60E+03	Negligible	Negligible	Negligible	Negligible
^{228}Ra	Radium-228 + D	2.48E-02	<0.01[b]	1	5.75E+00	Negligible	Negligible	Negligible	Negligible
^{227}Ac	Actinium-227 + D	2.83E-03	<0.01[b]	1	2.18E+01	Negligible	Negligible	Negligible	Negligible
^{229}Th	Thorium-229 + D	1.83E-03	<0.01[b]	1	7.34E+03	Negligible	Negligible	Negligible	Negligible
^{232}Th	Thorium-232	1.25E-03	<0.01[b]	1	1.41E+10	Negligible	Negligible	Negligible	Negligible
^{231}Pa	Protactinium-231	6.54E-03	<0.01[b]	1	3.28E+04	Negligible	Negligible	Negligible	Negligible

Table 7-5. Cumulative Effects of Radionuclides in SST S-112 Residual Waste (4,144 ft^3). (2 sheets)

Isotope	Isotope Name	Inventory (Ci)	Ground Water Concentration at WMA Fence Line (pCi/L)	K_d (ml/g)	Half-Life (yr)	Incremental Lifetime Cancer Risk		Drinking Water Dose	
						Industrial Scenario[a]	Residential Scenario[a]	All Pathways Farmer[a] (mrem/yr)	Target Organ (mrem/yr)
^{232}U	Uranium-232	1.32E-01	<0.01[b]	0.6	6.98E+01	Negligible	Negligible	Negligible	Negligible
^{233}U	Uranium-233	5.55E-01	2.02E-02	0.6	1.59E+05	7.32E-09	3.76E-08	4.10E-03	NBP
^{234}U	Uranium-234	4.81E-01	1.78E-02	0.6	2.46E+05	6.33E-09	3.25E-08	3.53E-03	NBP
^{235}U	Uranium-235 + D	2.02E-02	<0.01[b]	0.6	7.04E+08	Negligible	Negligible	Negligible	Negligible
^{236}U	Uranium-236	1.31E-02	<0.01[b]	0.6	2.34E+07	Negligible	Negligible	Negligible	Negligible
^{238}U	Uranium-238 + D	4.56E-01	1.74E-02	0.6	4.47E+09	7.71E-09	4.09E-08	3.26E-03	NBP
^{237}Np	Neptunium-237 + D	1.38E+00	<0.01[b]	1	2.14E+06	Negligible	Negligible	Negligible	Negligible
^{238}Pu	Plutonium-238	1.10E+00	<0.01[b]	1	8.77E+01	Negligible	Negligible	Negligible	Negligible
^{239}Pu	Plutonium-239	4.85E+01	<0.01[2]	1	2.41E+04	Negligible	Negligible	Negligible	Negligible
^{240}Pu	Plutonium-240	8.61E+00	<0.01[2]	1	6.56E+03	Negligible	Negligible	Negligible	Negligible
^{241}Pu	Plutonium-241 + D	4.47E+01	<0.01[b]	1	1.44E+01	Negligible	Negligible	Negligible	Negligible
^{242}Pu	Plutonium-242	4.08E-04	<0.01[b]	1	3.74E+05	Negligible	Negligible	Negligible	Negligible
^{241}Am	Americium-241	7.98E+01	<0.01[b]	1	4.33E+02	Negligible	Negligible	Negligible	Negligible
^{243}Am	Americium-243 + D	5.87E-03	<0.01[b]	1	7.37E+03	Negligible	Negligible	Negligible	Negligible
^{242}Cm	Curium-242	1.08E-03	<0.01[b]	1	4.46E-01	Negligible	Negligible	Negligible	Negligible
^{243}Cm	Curium-243	1.83E-05	<0.01[b]	1	2.85E+01	Negligible	Negligible	Negligible	Negligible
^{244}Cm	Curium-244	4.53E-04	<0.01[b]	1	1.81E+01	Negligible	Negligible	Negligible	Negligible
Peak Value						**6.70E-05**	**4.26E-04**	**4.45E+01**	**2.19E+02**

[a] Exposure pathways (i.e., ingestion, garden produce, etc.) for each exposure scenario as defined in HNF-SD-WM-TI-707.

[b] Concentrations below 0.01 pCi/L are considered to be effectively 0.

NBP = Not a beta/photon emitter.

Note: All radionuclides and all hazardous chemicals in SST S-112 for which there is toxicity/carcinogenic data [a reference dose (Rfd), cancer potency factor (CPF), or cancer slope factor (SF)] have been considered in the risk assessment. This analysis uses Reference Doses and Slope Factors, along with associated references, from Appendix A, Section 3.8, p. A-79 of HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for the Hanford Tank Waste Performance Assessments.*

Table 7-6. Cumulative Effects of Chemicals in SST S-112 Residual Waste (4,144 ft^3).

CASRN	Chemical	Inventory (Kg)	Ground Water Concentration at WMA Fence Line (mg/L)	K_d (ml/g)	Incremental Lifetime Cancer Risk				Hazard Index			
					Industrial Scenario[a]	Residential Scenario[a]	MTCA C Industrial Scenario	MTCA B Residential Scenario	Industrial Scenario[a]	Residential Scenario[a]	MTCA C Industrial Scenario	MTCA B Residential Scenario
7429-90-5	Aluminum	7.61E+03	<1E-5[b]	1	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
18540-29-9	Chromium	1.21E+02	2.04E-02	0	3.05E-07	7.16E-07	NDF	NDF	7.91E-02	4.76E-01	2.10E-01	5.24E-01
16984-48-8	Fluoride	6.74E+01	9.48E-03	0.01	NDF	NDF	NDF	NDF	1.57E-03	1.10E-02	4.51E-03	9.87E-03
7439-89-6	Iron	1.15E+03	<1E-5[b]	1	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
7439-96-5	Manganese	2.41E+02	<1E-5[b]	1	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
7439-97-6	Mercury	2.74E+00	<1E-5[b]	1	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
7440-02-0	Nickel	5.76E+01	<1E-5[b]	1	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
14797-55-8	Nitrate	4.56E+03	7.71E-01	0	NDF	NDF	NDF	NDF	4.77E-03	3.07E-02	1.38E-02	3.01E-02
14797-65-0	Nitrite	1.29E+03	2.18E-01	0	NDF	NDF	NDF	NDF	2.15E-02	1.38E-01	6.22E-02	1.36E-01
7440-24-6	Strontium	3.94E+01	<1E-5[b]	1	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
7440-61-1	Uranium	1.37E+03	5.19E-05	0.6	Negligible	Negligible	Negligible	Negligible	8.58E-04	6.00E-03	2.47E-03	5.41E-03
11097-69-1	Aroclor-1254	1.05E-02	<1E-5[b]	1	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Peak Value					**3.05E-07**	**7.16E-07**	**--**	**--**	**1.07E-01**	**6.54E-01**	**2.91E-01**	**7.00E-01**

[a] Exposure Pathways (i.e., ingestion, garden produce, etc.) for each Exposure Scenario as defined in HNF-SD-WM-TI-707.

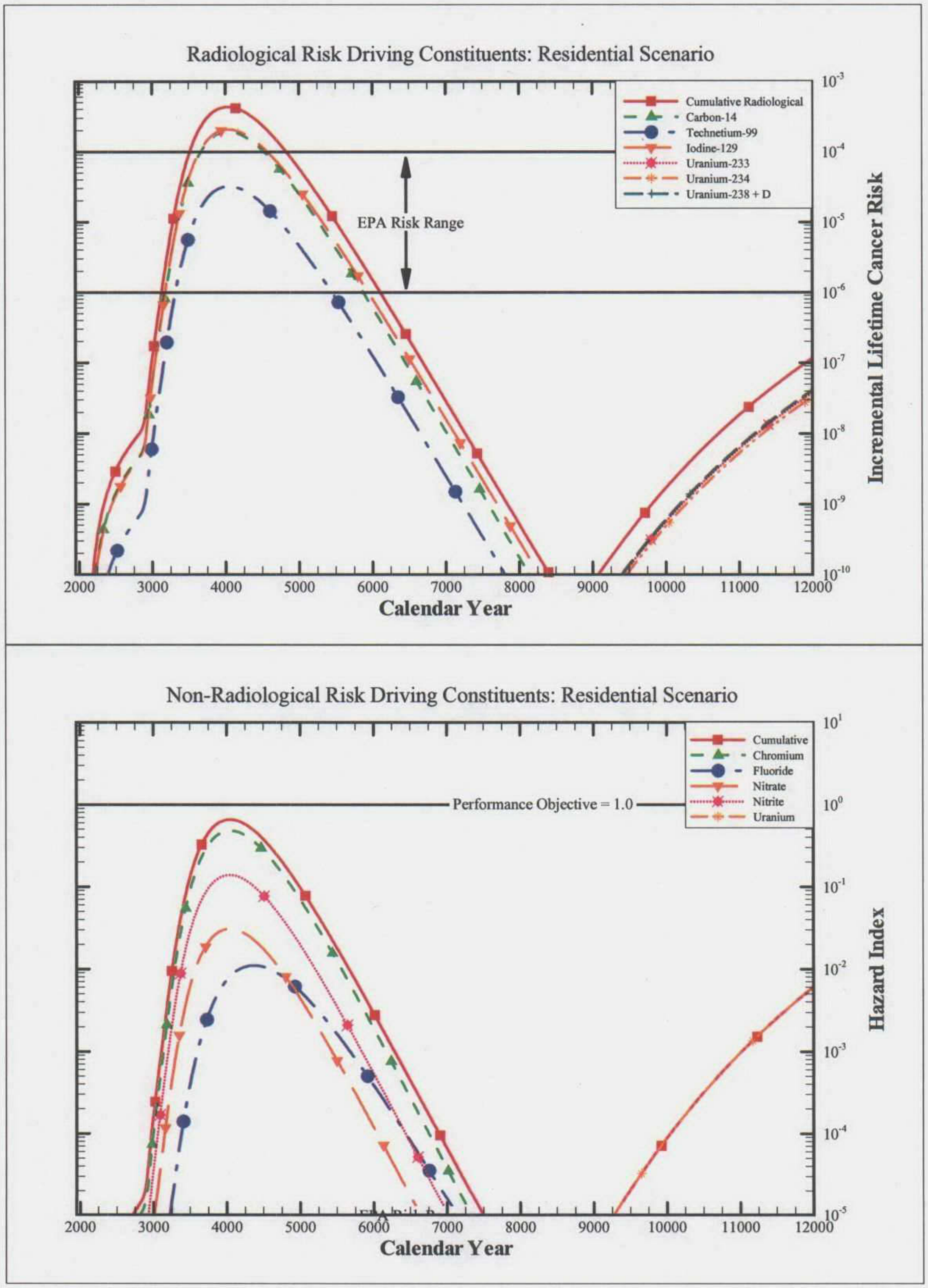
[b] Concentrations below 1.0E-5 mg/L are considered to be effectively 0.

MTCA = Model Toxic Control Act

NDF = No slope factors available for this metric.

Note: All radionuclides and all hazardous chemicals in SST S-112 for which there is toxicity/carcinogenic data (a reference dose, cancer potency factor, or cancer slope factor) have been considered in the risk assessment. This analysis uses Reference Doses and Slope Factors, along with associated references, from Appendix A, Section 3.8, p. A-79 of HNF-SD-WM-TI-707, Rev. 4, *Exposure Scenarios and Unit Factors for the Hanford Tank Waste Performance Assessments*

Figure 7-7. Contribution of Major Risk-Driving Contaminants Over Time to the Cumulative Risk (top plot) and Cumulative Hazard Index (bottom plot).



7.9 CONCLUSIONS

Inventory calculations (Section 7.3) based on BBI data provide the best estimate based on available data at this time. This estimate involves a set of assumptions, uncertainties, and inconsistencies that contribute to margin of error in the risk assessment. To improve accuracy of the inventory estimate, sampling the residual waste is necessary on completion of final retrieval. Further retrieval of SST S-112 using an additional available technology is planned to achieve retrieval criteria established in Milestone M-45-00. On completion of additional SST S-112 retrieval, sampling of the residual waste will be conducted. Characterization of the final waste will be performed so that the risk assessment can be updated.

Assuming that SSTs S-110 and S-111 are retrieved to the HFFACO residual limit, major conclusions from the risk assessment described in Sections 7.7 and 7.8 are the following:

a. The risks posed by the residual waste in SST S-112 after the retrieval demonstration are above the performance objectives for APF and TODWD and close to the upper limit for ILCR-rad (see Table 7-7).

b. Principal risk-driving radionuclides are ^{129}I, ^{14}C, ^{14}Tc, and the uranium isotopes, with ^{129}I and ^{14}C accounting for the majority of the dose/risk.

Table 7-7 presents a comparison of the cumulative risks to an industrial receptor from the 4,144 ft^3 residual waste in SST S-112 against the respective performance objective for WMA S-SX to meet the HFFACO residual limit. Additionally, the pre-retrieval estimated cumulative risks given in RPP-21596 are provided.

Table 7-7. Cumulative Risks to an Industrial Receptor from Peak Groundwater Concentration Related to Residual Waste in SST S-112.

Cumulative Risk Metric	Industrial Receptor		
	Post-Retrieval (4,144 ft^3)	Performance Objective[a] (360 ft^3)	Pre-Retrieval[b] (estimated 360 ft^3)
Industrial receptor for all radionuclides ILCR	6.7E-05	1.0 E-04 to 1.0 E-06[c]	2.11E-05
Industrial receptor for all nonradioactive chemicals ILCR	3.1E-07	1.0 E-05[d]	9.00E-07
Hazard Index	1.1E-01	1.0[c]	3.30E-01
APF dose (EDE)	45 mrem/yr	15 mrem/yr[c] or 25 mrem/yr[e]	4 mrem/yr
Target organ dose	219 mrem/yr	4 mrem/yr[f]	19 mrem/yr

[a] The performance objectives apply to the WMA, not just a single component of the WMA.
[b] Risks estimated using residual release model described in RPP-21596.
[c] EPA/540/R-99/006 *Radiation Risk Assessment at CERCLA Sites: Q & A Directive* 9200.4-31P.
[d] *Performance Objectives for Tank Farm Closure Risk Assessment* (RPP-14283).
[e] DOE Order 435.1 on *Radioactive Waste Management*.
[f] Title 40 *Code of Federal Regulations*, Parts 9, 141, and 142 "National Primary Drinking Water. Regulations; Radionuclides; Final Rule" (40 CFR 9, 141, 142).

As shown in Table 7-7, the estimated cumulative risks of the 4,144 ft^3 of residual waste in SST S-112 do not meet all performance objectives prescribed in RPP-21596, in which SST S-112 is assumed to contain 360 ft^3 of residual waste. Additional reduction in inventory is necessary to reduce the risks and doses to regulatory performance objectives and to meet the HFFACO residual limit (360 ft^3) for closure of SST S-112. Further retrieval of SST S-112 using an additional available technology is planned to achieve retrieval criteria established in Milestone M-45-00. On completion of additional SST S-112 retrieval, sampling of the residual waste will be conducted. Characterization of the final waste will be performed and the risk assessment updated. This risk assessment will analyze all scenarios that are pertinent to the closure of SST S-112, including the inadvertent intruder scenario and the Native American scenario

8.0 ADDITIONAL AVAILABLE TECHNOLOGIES

This section describes, compares, and evaluates additional waste retrieval technologies that are currently available for additional retrieval in SST S-112. It also describes potential waste retrieval technologies requiring research and development that could be deployed at the Hanford Site in the future but are not sufficiently mature to consider for deployment at this time.

The saltcake retrieval demonstration at SST S-112 was the first completed retrieval of saltcake from an SST. The saltcake dissolution retrieval in SST S-112 served to demonstrate and evaluate the state of this technology and provide data for future retrievals. The selection and deployment of future waste retrieval technologies depends in part on lessons learned from past activities. Lessons learned from this demonstration retrieval are set out in Sections 3.4 and 4.5 of this RDR. Lessons learned that are most appropriate to evaluation and selection of retrieval technologies include the following:

a. The dissolution rate of saltcake waste is proportional to temperature. Therefore, higher temperatures should lead to higher dissolution rates.

b. Waste dissolution rates may be optimized by allowing more effective recirculation of brine.

c. The Fury nozzle used in the saltcake retrieval demonstration was overly sensitive to operating pressures and had limited use.

d. The dissolution rate of dense saltcake material using the S-112 saltcake dissolution system would be so slow as to either be ineffective or require an excessive volume of water to retrieve the saltcake. Methods should be devised to increase the surface area of the saltcake.

e. Sampling and characterizing the tank waste through all tank layers before retrieval begins can benefit future retrievals. Pre-retrieval characterization data may provide indication of potential retrieval difficulties and may aid technology selection.

f. Achieving better distribution on recirculation lines would result in contact with more waste and minimization of fresh water volumes added to tanks.

Two technologies, the remote water lancing alternative discussed in Section 8.1.3 and the ex-tank water heater on recirculation line alternative discussed in Section 8.1.4, directly relate to lessons learned during the SST-S-112 retrieval demonstration. Guidance drawn from the lessons learned can be used to develop and implement additional improvements for future retrieval actions.

8.1 AVAILABLE WASTE RETRIEVAL TECHNOLOGIES

Additional waste retrieval technologies were evaluated using a three-step process:

a. Identifying the ability of technologies to perform necessary retrieval functions. Functions identified as necessary include the following:

   1. Breaking up hard saltcake waste.
   2. Dissolving waste.
   3. Mobilizing/moving waste in the tank.

   4. Transferring waste out of tank.
   5. Minimizing residual waste volume.

b. Identifying technologies and alternatives that could be deployed in SST S-112 with minimal research and development.

c. Comparing the relative effectiveness of technologies/alternatives against performance objectives.

Currently available retrieval technologies that could be scheduled for deployment in SST S-112 include the following:

a. **Modified Sluicing**—Consists of a sluicing system (water supply, nozzles, and controls), a centralized pump, and a transfer system. Modified sluicing has been or is currently being deployed on saltcake[1] and sludge[2] tanks. Three modified sluicing technologies were evaluated:

   1. Raw water modified sluicing.
   2. Remote water lancing.
   3. Ex-tank water heater on recirculation line.

b. **Mobile Retrieval System**—The mobile retrieval system combines a nozzle system with an in-tank vehicle . A similar system is currently slated for SST deployment.[3] The mobile retrieval system is typically identified as an appropriate retrieval technology for leaking 100-series tanks.

c. **Alternative Sluicing or Recirculation Systems**—These systems alter existing sluicing systems to improve dissolution and retrieval.

8.1.1 Comparative Evaluation of Available Retrieval Alternatives

Each of the alternatives discussed in this section pose technical challenges and risks that may inhibit their capacity to attain the HFFACO retrieval criteria. Among the areas of technical uncertainty are the following:

a. The mobile retrieval system has yet to be demonstrated in Hanford SSTs. Demonstration projects are planned to establish the technical limits for this technology. However, until the demonstrations on 100-series tanks are completed, assurance that the mobile retrieval system technology could retrieve waste to HFFACO retrieval criteria remains uncertain.

b. Three of the technologies involve deployment of modified sluicing using existing or new equipment (end effectors or recirculation systems) under new riser configurations. The 2003-2005 retrieval campaign at SST S-112 involved several mid-campaign optimizations of equipment and/or operations that enhanced retrieval effectiveness but failed to complete retrieval of waste to HFFACO retrieval criteria. Further optimizations based on lessons learned and incorporated into the different forms of modified sluicing may result in additional waste retrieval; however, the quantity of waste that would be retrieved under the alternatives is uncertain.

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[1] SSTs S-102 and S-112.
[2] Used in the 2003 retrieval of SST C-106 and planned for SSTs C-103 and C-108.
[3] SSTs C-101, C-110, and C-111.

c. One technology involves the use of a high pressure, low volume system. This type of system has not been demonstrated for retrieval operations. High pressure systems have been used as "lances" to install equipment in saltcake tanks but not as methods of waste retrieval.

d. No sample has been obtained of the hard salt material in SST S-112. Therefore, predictions of technological effectiveness are difficult in regard to the extent to which remaining waste will dissolve or break up into sizes small enough for pumping compared to the amount of waste that will remain in chunks too large to pass through the pump screen.

8.1.2 Raw Water Modified Sluicing Alternative (Current Equipment)

In the *raw water modified sluicing alternative*, the current SST S-112 modified sluicing system would be restarted and operated to remove tank waste until M-45-00 retrieval criteria are satisfied. Restarting the SST S-112 modified sluicing system would include the following steps:

a. Complete or interrupt SST S-102 waste retrieval. Equipment and resources required to retrieve additional waste from SST S-112 are not available until completion or interruption of SST S-102 waste retrievals. If this approach were to be followed, it is not clear that retrieval milestones for SST S-102 would be met.

b. Add water via nozzles, recirculate, soak, and pump until the limit of technology is achieved.

c. Evaluate the remaining volume.

d. Collect samples and characterize.

e. Decommission equipment.

The hard saltcake in SST S-112 is resistant to dissolution due to the low effective surface area. The declining rate of retrieval seen in SST S-112 indicates that this process would take more than one year. Heated water added to the surface of the waste accelerates dissolution of the saltcake, but this potential process improvement is negated by the endothermic dissolution reaction. The residence time for soaking would be extended to increase the density of the brine before transferring to the DST system. A minimum brine density is needed to preserve enough DST space for continued S Farm retrievals, or a penalty of additional evaporator runs is incurred.

The volume of DST space required to attain the minimum volume goal is estimated to be 763,000 gal. The volume of DST space required is greater than the volume estimated for the remote water lance in section 8.1.3 because a lower retrieval efficiency is expected. Some of the salt would likely be removed by direct particulate sluicing while the density of the dissolved salt solution is not expected to meet the desired concentration. In addition, about 100,000 gal of water for flushing would be added.

8.1.3 Remote Water Lancing Alternative

The *remote water lancing alternative* consists of modified sluicing using a low volume and high pressure water lance. The high pressure is delivered in close proximity to the waste while submerged under several inches of water to reduce misting. The high pressure system is expected to cut into the hard saltcake to increase effective surface area while breaking the waste into smaller pieces. This system can be used in combination with soaking and recirculation to increase the rate of waste dissolution and removal. The system includes a remotely controlled "nozzle" to deliver the high pressure stream in close proximity to the waste. The existing pump and recirculation system can be retained. This system would also break up and move toward the pump any large chunks of waste that are relatively insoluble.

The volume of DST space required to attain the minimum volume goal is estimated to be 145,000 gal. In addition, about 100,000 gal of water for flushing would be added. These estimates assume that all of the remaining waste is relatively soluble with a minimal sludge component. Implementing the remote water lancing alternative would include the following steps:

a. Complete or interrupt SST S-102 waste retrieval. Equipment and resources required to retrieve additional waste from SST S-112 are not available until completion or interruption of SST S-102 waste retrievals.
b. Install a high pressure delivery system.
c. Add high pressure water via new nozzles, add low pressure water as needed with existing nozzles, recirculate, soak, and pump until the limit of technology has been achieved.
d. Evaluate the remaining volume.
e. Collect samples and characterize.
f. Decommission equipment.

8.1.4 Ex-Tank Water Heater on Recirculation Line Alternative

The *ex-tank water heater on recirculation line alternative* is based on the use of a heater on the recirculation line outside of the tank. The purpose of the heater would be to improve the rate of saltcake dissolution. The rate of saltcake dissolution is proportional to temperature. The dissolution of saltcake is an endothermic reaction; the solution cools as dissolution progresses. If dissolution is rate-controlled by temperature, maintaining a higher solution temperature would improve the rate of dissolution. Existing tank equipment would be used for adding water, recirculation, and pumping the waste solution.

The volume of DST space required to attain the minimum volume goal is estimated to be 446,000 gal. This volume is lower than that for the option in Section 8.1.2 because more efficient dissolution is expected, but it still is not expected to provide the degree of dissolution provided by the remote water lance. In addition, about 100,000 gal of water for flushing would be added. This estimate assumes that all of the remaining waste is relatively soluble with a minimal sludge component. Implementing the ex-tank water heater on recirculation line alternative would include the following steps:

a. Complete or interrupt SST S-102 waste retrieval. Equipment and resources required to retrieve additional waste from SST S-112 are not available until completion or interruption of SST S-102 waste retrievals.
b. Install a heating system on the recirculation line.
c. Add water via nozzles, recirculate, soak, and pump until minimum volume goal or lower is achieved.

d. Evaluate volume remaining.

e. Collect samples and characterize.

f. Decommission equipment.

8.1.5 Mobile Retrieval System Alternative

The *mobile retrieval system alternative* consists of a mechanical system installed on an in-tank vehicle. The purpose of the mechanical system would be to break up the saltcake to improve the rate of saltcake dissolution. The rate of dissolution is dependent on the effective surface area of the exposed saltcake.

The mobile retrieval system can be used in combination with soaking and recirculation to increase the rate of waste dissolution and removal. The in-tank vehicle could also add water to the waste. Existing tank equipment would also be used for adding water, recirculation, and pumping of the waste solution, although at least one of the existing nozzles would need to be replaced. The in-tank vehicle could also be used to break up insoluble chunks of waste and move them toward the pump.

The volume of DST space required to attain the minimum volume goal is estimated to be 446,000 gal. The volume for MRS retrieval is about the same as that for the option in Section 8.1.4 because similar starting and ending retrieval efficiencies are predicted, although the retrieval options are markedly different. In addition, about 100,000 gal of water for flushing is added. This estimate assumes all of the remaining waste is relatively soluble with a minimal sludge component. Implementing the mobile retrieval system alternative would include the following steps:

a. Complete or interrupt SST S-102 waste retrieval. Equipment and resources required to retrieve additional waste from SST S-112 are not available until completion or interruption of SST S-102 waste retrievals.

b. Remove saltwell equipment from the 42-in. riser or install in a new riser.

c. Install an in-tank vehicle system.

d. Add water via nozzles, recirculate, soak, and pump until minimum volume goal or lower has been achieved.

e. Evaluate volume remaining.

f. Collect samples and characterize.

g. Decommission equipment.

8.1.6 Modified Recirculation System Alternative

The purpose of the modified recirculation system is to provide additional sluicing capability during recirculation. The distinction between the existing system and the *modified recirculation system alternative* is that in the modified recirculation system alternative, the recirculation system is attached to new recirculation nozzles. The system adds water via these nozzles and recirculates the liquid. Used in combination with soaking, the modified recirculation system could increase the rate of waste dissolution and removal. The system might also break up and move insoluble waste toward the pump.

The volume of DST space required to attain the minimum volume goal is estimated to be 193,000 gal. In addition, about 100,000 gal of water for flushing would be added. This volume is less than all other options except the remote water lance because an increased retrieval efficiency is predicted for this option. It is not predicted to be as efficient as the remote water lance however. This estimate assumes that all of the remaining waste is relatively soluble with a minimal sludge component. Implementing the modified recirculation system would include the following steps:

a. Complete or interrupt SST S-102 waste retrieval. Equipment and resources required to retrieve additional waste from SST S-112 are not available until completion or interruption of SST S-102 waste retrievals.

b. Connect the recirculation system to the nozzles.

c. Add water via nozzles, recirculate, soak, and pump until minimum volume goal or lower has been achieved.

d. Evaluate volume remaining.

e. Collect samples and characterize.

f. Decommission equipment.

8.1.7 Estimated Schedules and Costs for Alternatives

The estimated schedules shown in Table 8-1 are based on the alternatives developed for SST C-106 (RPP-20577, *Stage II Retrieval Data Report for Single-Shell Tank 241-C-106*, Section 4) and are not adjusted to include cross-site transfer delays. The mobile retrieval system is the most complicated approach and requires the longest combined period for development, installation, and operation. Raw water modified sluicing uses currently installed equipment but has an extended operational period. The other alternatives require extensive design and ex-tank modifications.

Table 8-1. Estimated Schedule.

Retrieval Alternative	Description	Quarters from Start of Project					
		1	2	3	4	5	6
Raw water modified sluicing (current equipment)	Raw water modified sluicing (current equipment)						
Remote water lancing	Remote water lancing						
Ex-tank water heater on recirculation line	Ex-tank water heater on recirculation line						
Mobile retrieval system	Mobile retrieval system						
Modified recirculation system	Modified recirculation system						

The costs for the alternatives are based on the SST C-106 costs (RPP-20577, Appendix C) with some adjustment for water use and evaporator costs. The mobile retrieval system is the most complex and expensive. When considered for SST C-106, the installation and operation of the mobile retrieval system was approximately $10 million with 30% contingency for a total cost of approximately $13 million (RPP-20577, Table 4-3). The same cost was assumed for this application.

Evaporator costs are estimated to be $2 per gal.[4] Costs for evaporator operation are shown in Table 8-2.

Table 8-2. Evaporator Costs.

Alternative	Raw Water Modified Sluicing (Current Equipment)	Remote Water Lancing	Ex-tank Water Heater on Recirculation Line	Mobile Retrieval System	Modified Recirculation System
Total volume to DST, gal	863,000	245,000	546, 000	546, 000	293,000
Total water for evaporation, gal	813,000	195,000	496, 000	496,000	243,000
Evaporator costs @ $2 per gallon	$1,626,000	$390,000	$992,000	$992,000	$486,000

The estimated total costs are shown in Table 8-3.

Table 8-3. Estimated Total Costs for Retrieval Alternatives.

Retrieval Alternatives	Estimated Retrieval System Cost ($)	Increase in Evaporator Costs ($)	Total Cost ($)
Raw water modified sluicing (current equipment)	2 million	1.6 million	3.6 million
Remote water lancing	5.7 million	0.4 million	6.1 million
Ex-tank water heater on recirculation line	5.7 million	1 million	6.7 million
Mobile retrieval system	13 million	1 million	14 million
Modified recirculation system	5.7 million	0.5 million	6.2 million

"Estimated retrieval system cost" includes all of the costs associated with modifying and replacing equipment plus the operating costs to complete retrieval. The remote water lancing, ex-tank water heater on recirculation line, and modified recirculation system alternatives are assumed to have similar complexity to the new modified sluicing with new slurry pump for the SST C-106 retrieval (RPP-20577, Section 4 and Appendix C). At the present level of system development and order of magnitude estimates, no cost differentiation can be made among the three alternatives. For cost differentiation to be practicable, improved project concepts, designs, and performance data would need to be prepared for each alternative.

[4] Based on RPP-20577, which cites ORP-11242, *River Protection Project System Plan*, projects processing 28 million gal (FY 2004-FY 2011) and baseline for same period assigns $51 million for evaporator operations. $51/28 gal = ~$2.00/gal, rounded.

8.2 POTENTIAL FUTURE RETRIEVAL TECHNOLOGIES

This section describes waste retrieval technologies that are not currently available for deployment in the Hanford Site tank farms. The technologies discussed in Sections 8.2.1 through 8.2.6 are at varying stages of development. Some may require substantial investment in research and development while others have been used elsewhere but would need to be adapted for use at the Hanford Site. Activities that would need to deploy these technologies could include engineering, procurement, testing, and construction. The discussion herein of these technologies is presented in summary form. Detailed information developed in the context of 241-C-106 is found in RPP-20577.

8.2.1 AEA Technology Power Fluidics™[5]

The power fluidic concept for sampling, mixing, and pumping tank wastes at the Hanford Site has been evaluated for several years. A search and evaluation of potential technologies recommended that fluidic mixing and pumping systems, such as developed by AEA Technology (AEAT), be considered to demonstrate dissolution retrieval of saltcake waste and also noted that the technology could prove suitable for mobilization and retrieval of insoluble solids (e.g., sludge waste).

Subsequently, evaluation and testing of the fluidic mixing and pumping was conducted for application in the Hanford Site SST retrieval program (RPP-20577). Testing results indicated that the fluidic mixing and pumping system did not fully meet objectives and that further development and demonstration would be required.

8.2.2 Russian Pulsatile Mixer Pumps/Fluidic Retrieval Systems

The Russian Integrated Mining and Chemical Combine fluidic concept for mixing and pumping tank waste is generally similar to the AEAT system but has design details different for the pump mechanism and nozzles. While the AEAT has no moving parts in the pump, the Russian unit employs a simple check valve mechanism. Both systems use two distinct cycles, fill and discharge, to perform mixing action.

The design and fabrication of the pulsatile mixer pump occurred in a Russian facility that does not work to U.S. standards, so full compliance with U.S. standards was not achieved. The alliance with American Russian Environmental Services, Inc., is intended to allow fabrication in the United States to U.S. standards in the future. The pump was capable of being deployed through a 22.5-in.-diameter opening.

Large-scale simulant tests of the concept for retrieving tank waste at the Hanford Site were observed in Russia by Hanford Site staff in 2002. As of the time that RPP-20577 was prepared, CH2M HILL had requested that DOE-Headquarters EM-21 fund the Russian fluidics concept to provide a lessons learned report following completion of that retrieval, and the request was under consideration.

[5] AEA Technology Power Fluidics™ is a registered trademark of AEA Technology, Harwell, England.

8.2.3 Small Mobile Retrieval Vehicles

8.2.3.1 Remotely Operated Vehicle Systems at Oak Ridge

During the period of 1996-1998, Oak Ridge National Laboratory deployed a series of hydraulically powered, remotely operated vehicles. The equipment was redesigned and improved. As redesigned, the frame was a 4 ft x 5 ft parallelogram style frame. Folding the frame enabled the device to deploy through a 24-in. tank riser. Many hardware failures occurred during deployment, requiring repair or replacement. The equipment was later used in other tanks in conjunction with a wall-washing tool (the linear scarifying end-effector), a confined sluicing end-effector, and a modified light-duty utility arm[6] (MLDUA).

8.2.3.2 Scarab III[7]

The Scarab III vehicles employ four rubber-treaded wheels for traction on slick surfaces and four metal wheels for biting into thin layers of waste. The Scarab can climb over 8-in. obstacles and has a manipulator arm. The manipulator gripper end-effector had a payload limit of 5 lb and requires an 18-in.-diameter access. The unit has three on-board cameras for viewing deployment, retrieval, and driving operations.

8.2.3.3 TMR Associates VAC TRAX[8]

The VAC TRAX is a remote-operated rotating high-pressure water jetting tool that directs ultra-high-pressure water to remove material coverings from a variety of surfaces; e.g., contaminated paint from concrete walls and floors. At higher pressures the equipment can perform light scabbling or deep scarification of concrete surfaces. The equipment is fully encapsulated with water and debris vacuumed from a manifold through a flexible vacuum hose. The system supplies water up to 36,000 psi through a rotating manifold containing orifices to produce a concentrated stream. A vacuum is applied to a shroud around the manifold; very little water volume is on the surface at any time.

8.2.4 Tank Wall Washing at West Valley Demonstration Project

During early stages of waste retrieval at the West Valley Demonstration Project, the retrieval process was very efficient. As the removal of the contents moved from bulk removal to heel and residue retrieval, the number of transfers and associated time per transfer climbed steadily ["Completing HLW Vitrification at the WVDP; The Approach to Final Retrieval, Flushing, and Characterization" (Hamel and Damerow 2001)]. Tethered robotics were evaluated but were not used for retrieval or characterization because of many obstructions in the tank. Riser-mounted arms and positioning systems were developed to provide the capability to wash residues from the internal surfaces of the tanks. Oxalic acid or mixed organic acids were not used because of concerns with the carbon steel tank integrity.

8.2.5 Dry Ice Blasting

Decontaminating surfaces using dry ice blasting is a relatively new cleaning process using solid CO_2 pellets. The pellets sublimate (convert directly from a solid blast pellet to a vapor) leaving no residue. This is envisioned as a sand-less sandblasting approach to dislodge hard to remove

[6] Modified Light Duty Utility Arm is a trademark of SPAR Aerospace, Ltd.
[7] Scarab III is a trademark of R.O.V. Technologies, Inc., Vernon, Vermont.
[8] VAC TRAX is a registered trademark of TMR Associates, Rutherford, New Jersey.

residue from the tank surfaces. The dry ice is accelerated by compressed air and requires between 80 to 100 psi and 120 to 150 cfm (Lapointe 2004, *Sand-less Sandblasting*). The EPA, in their fact sheet for alternatives to trichloroethane, identified dry ice blasting with solid pellets as a desirable alternative for cleaning metal surfaces [EPA-905-F-00-026, *Technical Fact Sheet for 1,1,1-Trichloroethane (TCA) Hazards and Alternatives*].

8.2.6 Modified Light-Duty Utility Arm

The modified light-duty utility arm (MLDUA) has a horizontal reach of 15 ft, a vertical reach of 50 ft below grade, and a payload of 200 lb. The MLDUA was developed at the Hanford Site and used at Oak Ridge for the cleanup of seven underground tanks either 25 ft or 50 ft in diameter. The MLDUA performed the following operations in support of tank waste cleanup operations:

a. Grasping a sluicer to allow deployment of a hose management arm into the tanks.
b. Holding and maneuvering the sluicer to remove tank waste and waste material.
c. Tank wall radiation surveys.
d. Tank wall material sample collection.
e. Tank wall cleaning operations with high-pressure water jets.
f. Vertical pipe cutting operations.
g. Pipe plugging operations.
h. Support for tank wall coring operations.

Shortcomings were observed in operation of the MLDUA. Although lessons learned were documented for both design and operations, the lessons have not been incorporated into any subsequent versions of the MLDUA.

8.3 CONCLUSIONS

As discussed in Section 3.4, several factors associated with the retrieval technology should be considered for further retrieval of SST S-112 residual waste and future SST saltcake waste. Evaluation of the feasibility and viability of other available retrieval technologies to retrieve additional waste from SST S-112 was made on several factors: (1) the estimated volume of water required, which affects DST space usage and evaporator costs, (2) operational flexibility, and (3) capability to either cut hard saltcake and break pieces into sizes small enough for retrieval or capability to dissolve the hard saltcake.

The remote water lancing technology uses the least water among the available alternatives. Therefore, it will require the least DST space and incur the lowest evaporator cost. Its operational capabilities appear flexible. Based on cold testing, the remote water lancing system appears to have the capability to cut the hard saltcake and increase effective surface area while breaking the waste into smaller pieces, allowing retrieval of additional residual waste in SST S-112.

The feasibility of developing additional retrieval technologies was considered, along with cost estimates and amount of additional waste that could be removed by each potential technology. Additional information needs to be obtained to permit clearer differentiation among these potential technologies.

9.0 RECOMMENDATIONS FOR FURTHER ACTION

Recommendations for further actions include the following:

Recommendation 1—Evaluate the deployment of the Remote Water Lance technology at SST S-112 to retrieve additional waste (expected completion in FY 2006) because the Remote Water Lance technology appears to be the best currently available alternative.

Recommendation 2—Select a technology, deploy the technology at SST S-112, and operate until the limits of technology are reached (expected completion no later than December 2007 in support of milestone M-45-13).

Recommendation 3—Follow the Appendix I process to complete retrieval at SST S-112 (expected completion no later than December 2007 in support of milestone M-45-13).

Recommendation 4—Use lessons learned as appropriate during the second retrieval of SST S-112 and during the retrieval of other SSTs.

a. Use salt dissolution as well as pumping rate information as a basis for retrieval duration.
b. Review the assumptions in the BBI calculation process against retrieval results.
c. The deployment of equipment, such as water hoses and tank exhauster systems designed for high temperatures, to permit greater sluicing water temperatures should be evaluated and considered for use.
d. Increasing the effectiveness of brine recirculation may improve waste dissolution rates; steps to increase the effectiveness of recirculation include installing movable discharge nozzles on recirculation lines, increasing discharge pressures, and balancing waste pump-out rates with fresh water input.
e. Nozzle performance and utility could be increased by increasing velocity and/or volume and increasing capability to direct spray remotely to different areas of a tank.
f. Considering the presence of a dense saltcake layer at the bottom of a tank or pre-retrieval sampling and characterization of tank waste through all layers can indicate potential retrieval difficulties and may affect the choice of technology.
g. Methods are needed to increase the surface area of saltcake, increase the temperature of retrieval fluids, and enable hard saltcake to be broken up for transfer with recycled supernatant.

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